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ELEMENTARY LESSONS

IN

PHYSICAL GEOGRAPHY.

OCEAN-WAVES. *(After J. M. W. Turner.)*

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IN

PHYSICAL GEOGRAPHY.

BY

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PREFACE.

A SIMPLE but systematic and yet interesting description of the familiar features of the Earth's surface may be regarded as a natural introduction to the teaching of science. Treated from this point of view, Physical Geography may be made a valuable instrument of education. To give it such importance the most advantageous method is to make use of the common knowledge and experience of the pupils, and, starting from this groundwork, to train them in habits of observation and in scientific modes of thought and inquiry among every-day phenomena. From the very outset the instruction should be as far as possible practical. A shower of rain, the flow of a brook, the muddy water of a river, the shape of a cliff, the outlines of a mountain, the undulations of a plain—these and the thousand other common features of landscape should be eagerly seized by the teacher and used as vivid illustrations of the broad fundamental

principles which it will be his main object that his pupils should thoroughly master. Thus employed, Physical Geography is not learnt as an ordinary task, but rather becomes a delightful recreation, in which, however, the observing faculty is exercised, the power of induction cultivated, and the imagination kept constantly active.

Having been long convinced that such a method of instruction would place this branch of science upon a firmer and broader footing in our educational system, and would moreover prove of great service in fostering a spirit of observation and reflection even among children, I projected many years ago the *Primer of Physical Geography*, which has been recently published in the series of *Science Primers*. The rapid sale of large impressions of that little work encourages the hope that the method advocated has been found successful in practice.

The present volume may be regarded as a further development of the same plan of instruction. As its title implies, it still deals mainly with the broad elementary questions of Physical Geography. It would have been impossible to find a place within its Lessons for the treatment of every branch of the wide subject, and as impossible, had it even been desirable, to

bestow equal fulness upon every branch for which room has been made. I have devoted most space to those aspects of the science which, in my own experience, have been found best suited for practical instruction. While as much general information as may be feasible should be communicated to them, young pupils cannot of course be expected to find the same interest in all divisions of the subject. It is of far more consequence to awaken in them a taste for such pursuits, and lead them to carry on the study of their own accord, than to try to charge their memories with dry facts and figures which, in the absence of intelligent and suggestive teaching, are too commonly meaningless and repulsive.

While, therefore, adhering to a systematic treatment, I have been led to dwell, for example, on the phenomena of the atmosphere at much greater length than is usual in elementary class-books. These phenomena are among the most familiar and universal features of the globe; examples of them can be constantly adduced, and they may thus be used with singular advantage to illustrate how the facts of science are observed and its laws are deduced.

I acknowledge with pleasure my obligations to my ... Mr. Buchan, who not only kindly allowed me

to make use of his Charts of Atmospheric Pressure and Temperature (which I have sought to render more effective by the use of shades of colour), but who also read over the proof-sheets of the first two chapters and gave me valuable suggestions on subjects regarding which he is so high an authority.

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ELEMENTARY LESSONS

IN

PHYSICAL GEOGRAPHY.

INTRODUCTION.

1. At night when the sky is clear, the largest stars seem to stand out in front, with others less in size and brightness crowding behind them. As we gaze into these depths still remoter and feebler twinkling points appear, until at last our eyes can no longer shape out any distinct specks of light. Such a sight impresses our minds, as nothing else can do so vividly, with the vastness of the Universe. We feel how comparatively small must after all be the distance which we can see into that "star-dust" which has been sown through the regions of space. And even when with the aid of a good telescope we return to these same skies, it is to find more cause than ever to acknowledge how immeasurably vast is that part of the Universe which man can thus explore, but at the same time to meet again with a vague limit, beyond which we cannot see, not because we have reached the utmost verge of creation, but because our instrument

can carry our vision no further. Far beyond that limit it may be that the regions of space contain other stars and systems, though too remote ever to be brought into view even by the most powerful telescopes which human skill could construct.

Astronomers have calculated the distance of some of the largest and nearest stars. But their figures, expressing sums of many millions of miles, are too vast to carry any definite ideas to our minds. When we reflect that each of those stars, from the brightest to the faintest twinkling point, is really a sun, many of them, no doubt, far vaster in size than our sun, but dwindled into such seeming feebleness by reason of their inconceivable distance, we cannot but feel what a little speck of dust, in comparison, must this dwelling-place of ours really be which we call the Earth.

2. It is useful to get this comparative insignificance of the Earth firmly realized by our minds. And in no way can this be done so well as by watching the starry sky, and learning what has been discovered regarding the motions, sizes, and distances of the heavenly bodies. What then is the Earth in relation to these bodies? Has it always been in the same condition as now, or has it perhaps passed through long ages of change and progress? Mankind has had a long and varied history. May not the Earth itself have had one also? If so, can we learn anything about the story of the Earth?

3. Again, when, on the other hand, we look upon the face of the Earth by day, how boundless and varied it seems! From the district in which we may chance to live, we can pass in thought to the country at large, then to other countries, and then to the idea of the whole wide globe, with its continents and oceans, its mountains, valleys, and plains, and all that wonderful diversity of form and colour which makes its surface so unceasingly beautiful.

4. This variety is everywhere associated with life and movement. Consider, for instance, the unvarying succession of day and night; the orderly march of the seasons; the constant blowing of the winds; the regular circling of the ocean tides; the ceaseless flow of rivers; the manifold growth and activity of plant and animal life! Surely it was no strange thought when men in old times pictured this world as a living being. And even though we cannot look on the earth as a living thing in the sense in which a plant or animal is so called, yet in view of all that multitudinous movement which is ever in progress upon its surface, and on which, indeed, we know that our own existence depends, there is evidently another sense in which we may speak of the life of the Earth.

5. Now this Life of the Earth is the central thought which runs through all that branch of science termed Physical Geography.[1] The word geography, as ordinarily used, means a description of the surface of the earth, including its natural sub-divisions such as continents, and oceans, together with its artificial or political sub-divisions, such as countries and kingdoms. But Physical Geography is not a mere description of the parts of the earth. It takes little heed of the political boundaries except in so far as they mark the limits of different races of men. Nor does it confine itself to a mere enumeration of the different features of the surface. It tries to gather together what is known regarding the Earth as a heavenly body, its constitution, and probable history. In describing the parts of the earth—air, land, and sea—it ever seeks so to place them before our minds as to make us realize, not only what they are in themselves, but how they affect each other, and what part each plays in the general system of our globe. Thus Physical Geography endeavours to

[1] This term as here used is synonymous with Physiography, which has been proposed in its stead.

[illegible] picture of the mechanism of [illegible] wonder-
[illegible] complex and harmonious with [illegible]
[illegible] of the facts with which this [illegible] explains
[illegible] familiar to everyone [illegible] which
[illegible] we [illegible] than with the [illegible]
[illegible] We have
[illegible] we know [illegible] as well as [illegible] as
[illegible] of [illegible]
[illegible] learn
[illegible] which we should [illegible] one
[illegible] Physical Geography [illegible] different
[illegible] to show how all these [illegible] to
[illegible] part
[illegible] explain their causes and to point out the [illegible] affect
which the [illegible] movements which [illegible]
[illegible] sea and land. This [illegible] of the great [illegible] character
of this study lies in the very [illegible] We cannot go
of the phenomena of which it treats [illegible] of
anywhere without meeting with illustrations of [illegible] once
the great lessons which it teaches. When we have [illegible] how
learnt these lessons, therefore, and have learnt [illegible] of
to apply them as we go, we carry [illegible] the
pleasure in every walk and [illegible] We [illegible] of
habit of using our eyes, and [illegible] endless variety by un-
things which would otherwise have been passed [illegible] the pleasure
seen, and this habit of observation, besides [illegible] service
its exercise brings with it, will be found of no slight
in the ordinary affairs of life.

7. In completing its picture of the Life of the Earth,
[illegible] Physical Geography must necessarily draw its illus-
[illegible] from all parts of the world. It thus brings before
[illegible] of which we may have no experience in
[illegible] and which very probably we may never
[illegible] In the
[illegible] of [illegible]

study of it, we journey, so to speak, all over the world, and learn in a short time far more about the world than we should be able to do from reading a few ordinary books of travel. Indeed, a good treatise on Physical Geography may be regarded as a condensed and well-arranged book of travels in all countries, with this distinction, that although it has no personal adventures to describe, it enables us to understand how one region of the earth differs from another, and explains these differences by connecting them all together with the general principles or laws on which they depend. So that, although a man may never have been in India or Africa, or the Arctic regions, he may from the study of Physical Geography have a far better notion of the general features of these countries, and why they differ from each other so much in climate, than many other men who have travelled to, or even lived for years in them. It is a matter of no little encouragement for all of us to know that the more we watch what takes place around us in our own country, and the more thoroughly we understand it, the more easily do we realize what goes on in other and distant parts of the world.

8. By taking up the study of Physical Geography, not merely as a subject to be learnt from books, but as a practical pursuit to be followed out by our own observations, as opportunity offers in the course of our daily occupations, we make most progress in it and get the largest amount of pleasure out of it. This is the spirit in which the following chapters are written. They are not meant merely to describe the different parts of the earth, in such a way as to enable you to learn these most easily by heart, but rather to incite you to use your own eyes, and to examine, compare, and contrast what you see to take place from day to day. They are so arranged as to begin, where practicable in each sub-division, with our common

knowledge. Then they point out what can be ascertained on the subject by our own simple observation and experiment. Lastly, they present such further information as may be acquired from the observations and travels of men who have given much time and thought to the collection and investigation of the facts. In the case of the Air, for example, starting from what each one of us knows by everyday experience, we shall proceed to consider what we can ourselves easily find out about the air, and from this basis of knowledge we shall follow what has been still further discovered by prolonged investigation in all parts of the world.

9. At the outset it may be well to group together in due order the different subjects which, coming within the scope of Physical Geography, will have to be attended to in these Lessons.

10. First of all we shall consider what the Earth is, as a heavenly body, how it is related to other heavenly bodies, and specially to the Sun, as the source of light and heat.

11. Secondly, looking at the Earth in itself, we find it wrapped round with an outer envelope of Air, which will next deserve our attention. What this envelope consists of, and the part it takes in the phenomena of the Earth's surface, furnish materials for much interesting inquiry.

12. Thirdly, beneath the surrounding shell of air, but covering the greater part of the surface of the solid globe, lies that vast expanse of water known as the Ocean. We shall follow its tides and currents, and trace the vapour which, ascending from its surface, is carried through the air until it falls as rain and snow upon the land, whence it is borne by rivers back again into the ocean. The wonderful beauty and high importance of this circulation will claim our attention.

13. Fourthly, the solid Land will be considered, with

its continents and islands, its mountains and valleys, its earthquakes and volcanos. The evidences of continual change in the surface of the land will lead us back to the action of the air and of water, and we shall find how largely the forms even of "the everlasting hills" have been determined by that action.

14. Fifthly, we shall inquire what Climate is, how different kinds of climate are distributed over the globe, and whether any causes can be assigned to account for such differences; this will lead us to note that as there is a geographical distribution of climates, so likewise is there one of plants and animals. Each great region of the earth's surface which has a peculiar climate of its own, has also its own distinguishing assemblage of peculiar plants and animals. Even in the way in which the races of man are grouped over the earth we shall find evidence of the same connection between the distribution of climates and of life. Thus the geographical distribution of Life over the earth's surface will form the concluding part of these Lessons.

CHAPTER I.

THE EARTH AS A PLANET.

LESSON I.—THE EARTH'S FORM.

1. What then is this Earth on which we live? The answer to this question must be chiefly given by astronomy, but there are some familiar features in the earth itself which, if rightly considered, help to make the answer more vividly realized. Evidently there is much advantage in obtaining a clear idea of what the earth is as a whole, before we begin to trace the events which take place upon its surface.

2. In the first place, then, the earth, like the sun and moon, is a globe. This may be proved in various ways.

(1) If we set sail from England and steer westward without turning back, we shall eventually find ourselves in England again. This is called **Circumnavigating the world.** It would not be practicable unless the earth were really a globe.

(2) Standing by the margin of the sea, and looking seawards, we observe that a ship which is moving away from us, by and by seems to sink into or under the sea. (Fig 1.) The hull first disappears, and then by degrees the sails. So, on the other hand, when a vessel approaches us, we can first, with a telescope, make out the tops of the sails and masts just peeping above the distant surface of the ocean. Little by little the sails rise as it were out of

the water, until at last the hull and the whole vessel come into sight. This could not happen unless the surface of the sea instead of being flat were really curved, that is, part of the curved surface of a globe.

(3) If the surface of the earth were flat, as men once supposed it to be, the sun would rise at the same time at all places on the earth. But this is not the case; sunrise takes place later or earlier as we travel west or east. Again, on ascending a mountain we should see the whole of the earth's surface if that surface were really a plain.

FIG. 1.—Curvature of the Earth's Surface, as shown by ships at sea.

But the extent to which we see depends on the height to which we climb. This shows that the earth must be a globe.

(4) When the earth comes directly between the sun and moon so as to cut off the light of the former from the latter, the moon is said to be eclipsed. Now, if we watch the earth's shadow as it creeps over the moon's surface, we see it to be circular, and hence we know that the real form of our planet must be that of a globe.

3. Were it possible for us to quit the earth and look back upon it from a distance of a few millions of miles it would appear as a large bright moon, hanging in space

[illegible] on all [illegible] of the moon, [illegible] and would be [illegible] dark strips [illegible] bright parts [illegible] the great

FIG. 2.—The Earth and Moon as seen from space.

[illegible] of snow and ice at the north and south poles. [illegible] these two areas, certain bright irregular bands [illegible] the position of the dry land, while the [illegible] portions would show the extent of [illegible] If we could transport ourselves still

further away; if, for instance, we could get as far off as the sun, that is to say more than ninety-one millions of miles from where we are living at this moment, our earth would be seen shining merely as a bright star. And were it possible for us to reach one of the nearest fixed stars, our globe would be no longer visible, while the sun itself if seen at all would appear merely as a twinkling star.

4. But the earth is not a perfectly regular sphere. In particular it is somewhat flattened on two opposite sides, so as to resemble an orange in shape. How this is known and measured will be seen from Lesson IV. A line from the middle of one of these flattened sides passing through the centre of the planet to the middle of the opposite flattened side, is called the Axis, and the points at which it reaches the surface are known respectively as the North Pole, and South Pole. A line drawn midway between the poles round the bulging part of the earth is termed the Equator.

LESSON II.—THE EARTH'S MOTIONS.

1. So long as men in early times looked upon the earth as a great plain placed in the centre of the universe, with sun, moon, and stars moving over and under it every day and night, they could not for a moment imagine that the Earth itself is moving. But the truth in this matter has now been so long known, that we have no difficulty in seeing how the apparent movements of the sun and stars are explained by the real movements of the earth. Of these movements the two chief are called Rotation and Revolution.

2. **Rotation.**—The most obvious movement of our earth is its rotation on its axis, to which the succession of day and night is due. A complete rotation is performed

in about twenty-four hours. During that time each part of the earth's surface is alternately presented to, and turned away from, the sun. As the sun rises in the east to give us day, and appears to travel westward across the sky, the real motion of the earth must be in the reverse direction, or from west to east.

3. It is evident that as the earth rotates, the rate of motion and the distance travelled will vary for different parts of the surface according to their nearness to or distance from the axis. When a cart-wheel, for example, is made to spin round on its axle, a mark made on its rim must move faster and describe a much larger circle than one made near the axle. Places situated on the earth's equator must have the maximum velocity and travel over the greatest distance, while at either pole the velocity must be *nil.* The circle described by a place on the equator is indeed the whole circumference of the globe. So that when the number of miles in the circumference is known and then divided by the number of hours required for a complete rotation, we obtain in figures the rate of motion. At the equator this rate is found to be upwards of 500 yards in a second; it gradually diminishes to the poles.

4. Now if the earth is rotating with such speed, why are we not jerked off its surface? When a stone is thrown into the air, why does it not immediately rush away into space instead of falling back again to the ground? Because what is called the earth's attraction is far stronger than this tendency to fly off. Everything in and on the surface is pulled down towards the centre of the earth by this attracting force, which is called gravity. But it will be seen that the influence of rotation is nevertheless unmistakably marked upon the great atmospheric currents, since these have their direction modified by it (Lesson XI. art. 13).

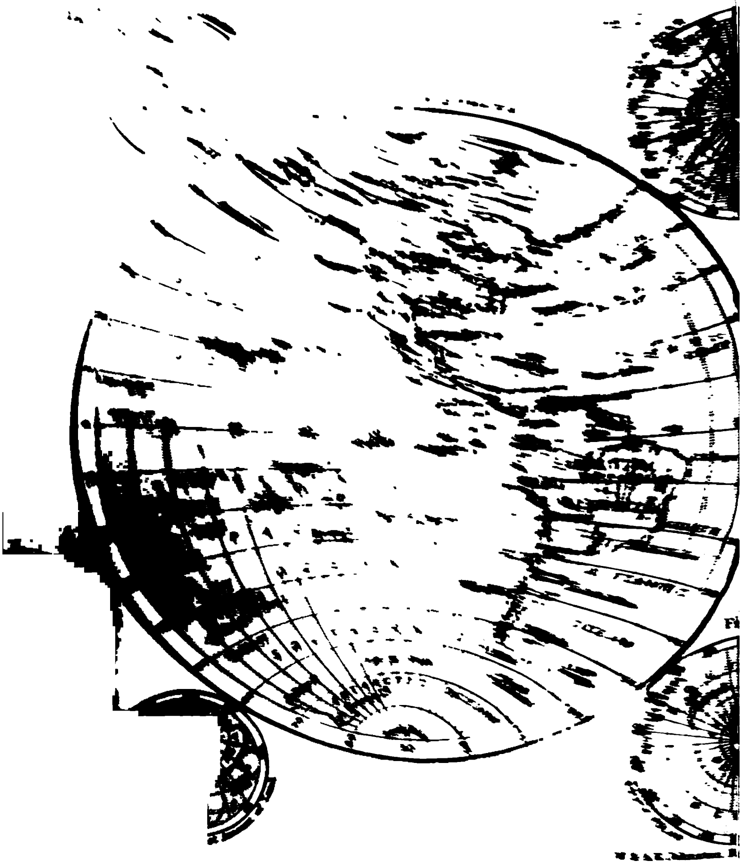


PLATE I.


Fig. 1
Longitudes or Meridians
North Temperate Zone
Torrid Zone
South Temperate Zone
EASTERN HEMISPHERE
North Pole
ARCTIC OCEAN
EUROPE
ASIA
AFRICA
ARABIA
INDIA
CHINESE EMPIRE
JAPAN
NORTH PACIFIC OCEAN
ARABIAN SEA
BAY OF BENGAL
CHINA SEA
Philippine
EQUATOR
INDIAN OCEAN
Madagascar
Sumatra
Borneo
Java
Celebes
AUSTRALIA
Tasmania
ATLANTIC OCEAN
SOUTH
C. of Good Hope
Kerguelen I.
SOUTHERN OCEAN
ANTARCTIC OCEAN
South Pole
REGIONS
Fig. 4
PACIFIC OCEAN
Hemisphere showing Greatest Amount of Water
and London

5. Revolution.—The earth revolves round the sun and takes about 365 days to perform the circuit. What we call a year is simply the length of time taken by the earth to make one complete revolution round the sun. The path which it follows, called its orbit, has been ascertained not to be a perfect circle but an ellipse, so that our globe is at one part of its course nearer to the sun than at another, its mean distance being computed at 91,328,600 miles. From this number and from the time taken for a single revolution it is easy to find the average rate at which our globe must rush along its orbit. That rate is about 68,000 miles in an hour.

6. There are certain circumstances connected with the movement of revolution which serve to explain why the days and nights throughout the year are not all of the same length, and why instead of perpetual summer or winter there is the regular succession of the Seasons. If the axis of the earth were perpendicular to the plane of the orbit, that is, if it moved along in a perfectly upright position, there would be equal day and night all the year round all over the globe. But it is really inclined to the path of the planet round the sun at an angle of about 23½° and remains always parallel to itself, that is, always points to the same star. In summer the North Pole is turned towards the sun, in winter it is turned away from it. Hence while midway between the two poles the day and night remain each of twelve hours' duration, they depart more and more from this uniformity towards the [illegible]les, until th[illegible]re we have a day lasting for one half of the [illegible]t lasting for the other half.

7. Ab[illegible] 22nd of March, and again about the 22nd [illegible] the earth is so placed in its orbit that the [illegible] vertical over the equator. The line be[illegible]-lit half and the dark half passes through [illegible] these times, therefore, day and night are

each of twelve hours' duration over the whole globe ; and these points in the year are accordingly called Equinoxes, that is, "equal nights." After the March equinox, the northern parts of the globe, as the earth moves round in its orbit, come more and more into the sunlight ;

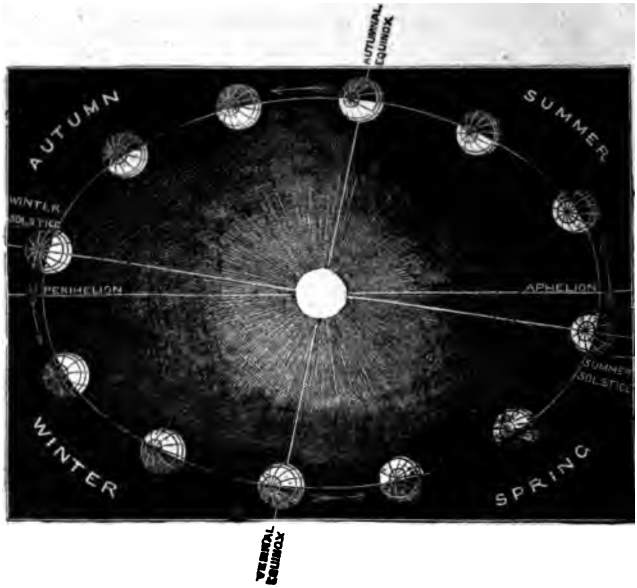


FIG. 3.—The Earth's path round the Sun.

in other words, the days get longer and longer until, at the North Pole and for a certain space all round it within what is called the Arctic Circle (see Plate I.), the sun does not set at midsummer at all, and there is continuous daylight. The further north we go the longer are the days in June, so that a summer-day in England differs very

much in length from one in India, and one in the north of Scandinavia from one in England. On the other hand, when the earth has got round to the September equinox, the North Pole is beginning to point away from the sun, and the days in the northern part of the earth begin to get shorter, till in mid-winter, at the pole and over the ground within the Arctic Circle the sun does not rise, and there is continued night. The further north we go in December, therefore, the longer are the nights; so that while a summer-day in London is not so long as a summer-day in the north of Scotland, a winter-day is considerably longer.

8. It is evident that when the North Pole is enjoying perpetual daylight, the South Pole must be in continuous night. It is only at the two equinoxes that their day and night are equal. As the days about the North Pole shorten, those at the opposite pole lengthen, and then the reverse takes place, and so on from year to year.

9. The alternation of the Seasons depends in like manner upon the inclination of the earth's axis in its yearly orbit. At one part of the year people in Europe and North America see the sun to be comparatively low in the sky: his rays are then but feeble; the climate is cold, and then comes the familiar sight of the frost and snow of *winter*. Six months later the sun appears much higher in the sky; that is, more directly overhead: his rays are then warm—even scorching, and we find ourselves in the midst of *summer*.

10. In reality, however, it is not the sun which has changed place, but our planet, which has reached different parts of its orbit, and consequently has presented itself in different positions towards the sun. In summer the days in the Northern Hemisphere (as the half of the globe between the equator and the North Pole is called) are long because the North Pole is turned towards the

sun. That hemisphere is consequently warmed. The rays of the sun come more directly down upon it; the long days allow much more heat to be received from the sun, and the short nights permit much less heat to be given off from the earth than in winter. While this state of things is going on in the Northern Hemisphere and brings summer there, precisely the opposite effects are taking place in the Southern Hemisphere. There, in proportion as the days lengthen and the warmth increases in the North, the days and the heat decrease, until at the midsummer of the Northern half of the globe, the people at the Antipodes, that is, on the opposite side, or Southern Hemisphere, are in their midwinter. Christmas, which in Europe and North America is always associated with the frost and cold of midwinter, happens at the midsummer of countries in the Southern Hemisphere, like Australia and New Zealand.

11. It is evident that the contrast between summer and winter must be most marked in the region round each pole, where indeed the year may be looked upon as consisting of only two seasons, one of daylight and summer, the other of night and winter. In the equatorial belt, too, that is on either side of the equator as far as the lines called the tropics, there is often a striking difference between the seasons according to the position of the sun in the sky. At each equinox the sun appears vertical over the equator. From March to June he seems to be travelling northward until about the 22nd of the latter month, when he shines vertically over a line called the Tropic of Cancer 23½° north of the equator. He then turns southward, is again vertical above the equator at the September equinox, after which he travels southward until about the 22nd of December, when he shines directly overhead along the line known as the Tropic of Capricorn 23½° south of the equator. The word tropic

means 'a turning' and is given because the sun after appearing to travel away from the equator begins to turn at these two limits on each side. The sun seems to be constantly travelling to and fro across the sky between the two lines of the tropics. This apparent movement of the sun is of course due to the real movement of the earth, and the limit within which the sun travels north and south of the equator is fixed by the angle of inclination of the earth's axis ($23\frac{1}{2}°$).

12. In the belt between the tropics the sun appears vertical in the sky twice in each year. With each of these periods comes a rainy season, and between them a dry and hot season. So that if no other influences came into operation the equatorial regions would have two wet and two dry periods in each year. Owing, however, to the way in which the wind currents are interfered with by the masses of high land, it is in such regions as that of the broad Pacific Ocean that this arrangement of the seasons is most completely carried out.

LESSON III.—THE EARTH AND THE SUN.

1. Long before Astronomy or any science had arisen, the early races of man, seeing how greatly the earth is dependent on the sun, worshipped that luminary as the great parent of all the light, and heat, and life of the world. And surely of all the forms of idolatry none is so natural as this. Before they knew what the sun really is, ...ght well be content to prostrate themselves before ...reat and good Being, who when he rose at dawn, ... and warmed the world, and when he sank at ...t in darkness and chill.

...ow or why is it that our light and heat come ...n? We know that the earth revolves round

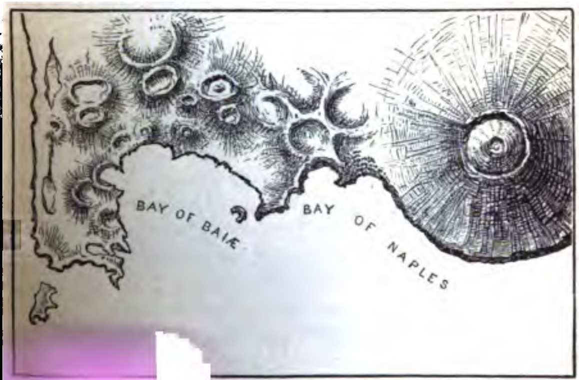
... ? Is it possible to know ... of the earth to the ... to these questions by ... which have been dis- ... In doing this we ... that the ... because ... part of one

... bore ... done ... more ... which ... have ... parts ... of ... are ... are ... observed ... well as ... drawn. ... And ... not ... as ... it ... not

... give out ... shines in

the sky, as the moon does, because like that orb it receives and reflects light from the sun.

7. Passing from the earth to the nearest of the heavenly bodies—the moon, which as the earth's s a t e l l i t e or attendant revolves round our globe while the latter is revolving round the sun—we find some wonderful evidence that the earth is not the only orb which shines with light borrowed from the sun, and though cool on the surface bears traces of the influence of internal heat.



ınic Hills and Craters in the Bay of Naples.

ıu e of this evidence may be followed by ·ings, Figs. 4 and 5. In Fig. 4, part of the neighbourhood of detached conical hills are : as Vesuvius is, or cold and s to the west of Naples. The ıe tops of these hills are the ·hich dust, cinders, steam, and

molten rock, have at different times been copiously discharged. In Lesson XXII. some account will be given of volcanoes, and it will there be shown how the streams of molten rock now and then run down the outside of the cone, while vast clouds of steam and hot dust, cast up with great violence, bear further witness to the intense heat of the interior.

9. Now with this little bit of the earth's surface compare the drawing in Fig. 5, which shows a portion of the

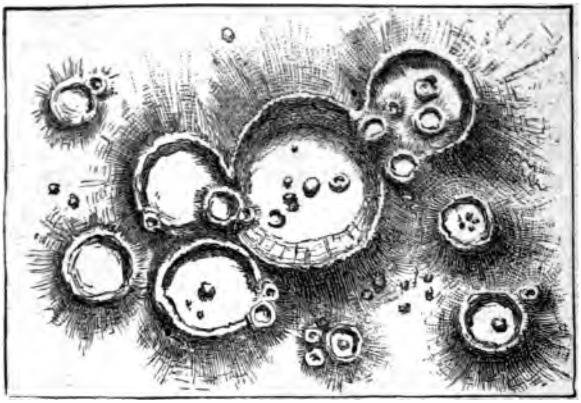


FIG. 5.—A Part of the Surface of the Moon showing Volcanic Craters.

surface of the moon. We observe in it a series of large "craters," with steep walls in the inside, and numerous smaller ones, sometimes in close-set rows. Several of the larger craters overlap each other, and in some cases their interior is crowded with the smaller ones, or the latter have broken through the ridges separating the great basins. So close is the likeness of this scene to such parts of the earth's surface as that shown in Fig. 4, that there seems

no reason why we should not call these conical elevations n the moon volcanoes, and look on their well marked craters" as really the openings whence molten rock and her hot materials have been thrown out, as in terrestrial canoes. So far as can be seen they abound over most the moon's surface. Indeed the lunar volcanoes have n measured by astronomers, and found to be far more erous, and greatly more gigantic than the terrestrial

We may fairly infer that they mark a much more se kind of volcanic action than anything we know of e earth. So that though the chill surface of the now gives out no light of its own, but only throws o us that which strikes upon it from the sun, the of that globe must once have been intensely hot, hardening crust through which the internal molten was poured by those hundreds of cauldron-like nd cracks.

o telescope has yet detected any actual volcanic going on in the moon. It would seem, indeed, once prodigious volcanic action there has spent that the inside of the moon, though perhaps r than the outside, has not heat enough left for bursts. Evidently the moon has cooled very e the time when its craters were active vol-

arth must be cooling likewise. The mere temperature between its surface and interior fact. The outer shell, or crust, would not than the inner mass unless there were a of heat from the earth into space. Heat is g outwards through the crust and surface, ot make the ground on which we walk , because as fast as it reaches the surface o space.

see that the earth cannot have been

always as it is now. A million of years ago it must have had considerably more heat than it possesses to-day. A hundred millions of years ago it was, perhaps, in the condition of a globe of molten matter, with no land or sea, and of course with no life of any kind upon its surface. The present flattening of its form at the poles is just the kind of shape which such a liquid globe would necessarily assume under the influence of rotation, and probably the permanent flattening dates from that time. Earlier still the earth might have existed merely in the state of vapour.

13. That this has really been its history has been thought by many philosophers to be in the highest degree probable, when, turning from the evidence which the earth itself presents, attention is given to that furnished by the sun. That the sun is hot has long been familiar knowledge, but only in recent years has any adequate notion been formed of how intense its heat actually is. One fundamental difference between the sun and the earth and moon is that its light is given out by itself, while theirs is only borrowed sun-light. When sun-light is examined by means of the spectroscope[1], it is found to indicate a temperature in the sun so enormously high that nothing can exist there except in the form of gas or vapour. The light and heat which we receive from the sun proceed from glowing vapours, among which have been detected those of some of the metals found on the earth only as solid bodies very difficult to melt. Probably most or all of the simple substances composing the earth exist also in the sun, but in the form of vapour. Were our globe thrown into the sun it would immediately be dissipated into the same glowing vapour.

14. Observation of the sun's surface has shown that

[1] For an account of the spectroscope and spectrum analysis see Roscoe's *Spectrum Analysis*, or Lockyer's *The Spectroscope and its Applications*.

spots which appear there are carried steadily round from west to east. This points to a movement of rotation, which, however, is slower than that of the earth. The sun, or at least its outer luminous envelope which we see, takes about twenty-five of our days to turn round once on its axis; but the movement is in the same direction as that of the earth.

5. Besides the earth and its attendant moon, a small number of other heavenly bodies has been found to revolve round the sun. If we note carefully the positions of the stars in the sky we find that, though the whole sky seems to travel slowly westward, each star keeps the same place with reference to the other stars. But at certain seasons we may observe some which look at first like stars, but which, when watched more attentively, may be seen to shift their place and to travel across the other stars. These were called by the ancients, planets, that is, wanderers. They are now known to be really revolving round our sun at different distances and in various periods of time. So far as can be judged from what the telescope shows, they closely resemble the earth in many points. They rotate on their axes. Some of them have a group of attendant moons. In some there are indications of an atmosphere with clouds and air-currents, and in one of them, called Mars, there appears to be a cap of snow and ice at each pole, as in the earth. Some are much larger, others much smaller than the earth; some are nearer to the sun than we, others greatly further away. This whole group of planets (including, of course, the earth), which has the sun as its centre, is known as the

…um up all these facts and see how they …nt condition and probable history of …he centre of the solar system stands …us globe of incandescent gas and

vapour, rotating on its axis, and sending forth heat and light far and wide through space. Round this central luminary, and depending on it for light and heat, a number of planets revolve in the same general plane, sometimes with minor planets or satellites revolving round them as the moon does round the earth. The planets show the same rotatory movement as the sun. The earth is one of the planets. Its present condition points to its once having been hotter than it now is, and possibly to its existence in a liquid or even gaseous state.

17. The nebular theory, which has been proposed to connect and explain these facts, maintains that at first the whole solar system existed only in the state of vapour, like one of the faint cloud-like nebulæ disclosed by the telescope among the stars; that this nebula gradually condensed and threw off from its hot mass successive portions, which, by subsequent condensation and cooling, became planets, and that the present sun is the remaining incandescent, but still slowly condensing and cooling nucleus of the whole, round which the various detached portions continue to revolve.

18. If the theory thus briefly sketched be a true one, and the discoveries of modern science go far to confirm it, it gives an intelligible reason for the intimate way in which the earth and the other planets are related to the sun. It furnishes a satisfactory explanation, too, of the fact that the inside of the earth is still hot, though slowly cooling. That internal heat, manifested, as we have seen, in every deep bore and mine, as well as in hot springs and volcanoes, appears thus as the residue of the original heat of the great nebula out of which the planets and the sun have been condensed.

;SSON IV.—MEASUREMENT AND MAPPING OF THE EARTH'S SURFACE.

It would not have been possible for geography to : much progress without some means of accurately taining the positions of places on the earth's surface. small scale we can measure with great exactness by ; of carefully-constructed chains or rods, how far lace is distant from another. But evidently this us method could have been of little use in laying he great features of the earth's surface, such as nts, islands, oceans, and the rest, or in discovering al dimensions of the planet itself. It was needful 1 some other method which could be easily used, ld give the means of determining with precision ion of every part of the surface of the globe. ıethod is supplied by observing the position of ıd different stars.

e note the height of the sun in the sky at noon, ıd that an hour after that time he seems to d a certain distance westward. In the course hour he will have traversed another similar so on hour after hour till nightfall. Next we again watch his progress, we detect a ıce hour by hour, until at noon he once more same position as at noon of the day before. al the earth has made one entire rotation ; carried round a complete circle.

ircle is divided into 360 equal parts, or d as we travelled round our circle in ours, we must have passed over fifteen hour. Suppose that some place, say the ervatory, is fixed on from which to count : is clear that all places lying to the east

of Greenwich have their noon earlier, and all places to the west have it later than at Greenwich itself. As the sun takes an hour to travel 15° of the circle, any place which has its noon exactly one hour after noon at Greenwich must lie 15° to the west.

4. To determine, therefore, how far we are to the east or west of Greenwich, we may try to find out the difference between Greenwich time and the local time at the place where we may be. This has been done for short distances by flashing mirrors, exploding gunpowder, or in any other way communicating an instantaneous signal from one point to another. The most efficacious method is by electric telegraph. But for long journeys, especially sea-voyages, where no such communication is possible, carefully-constructed clocks called chronometers are used, which show Greenwich time. By comparing the local time, as fixed by taking the sun's position, with the time shown in the chronometer, it is easily seen how far a place lies to the east or west of Greenwich.

5. But as even the most accurately finished clock is apt to gain or lose, there is still another and more reliable, though less convenient kind of observation—that of determining the position in the sky of the moon or some of the planets. The places which these bodies will have with reference to each other and to the fixed stars at any moment is calculated for a long time beforehand at the Greenwich Observatory, and tables showing these positions are printed. By referring to these tables the traveller finds the precise instant of Greenwich time, for each position of the heavenly bodies; and the difference between that time and the time he observes at the place where he is shows him whether and how far he is to the east or west of Greenwich. This is called "finding the longitude" of a place.

6. If we mark each of the 360 degreesin to which the

: same way if the line of the equator were pro-
it would traverse the heavens as a great circle.
g exactly its position in the sky or the distance of
venly body from it, we observe how far our zenith
ved from it, and thereby learn our distance from
estrial equator.

low the distance from either pole to the equator is
a quarter of a circle, or 90°. If we mark off the
es by a series of lines on the surface of the earth,
circles will run round the globe parallel to the
and to each other, but diminish in diameter as
vance to the pole. Such lines are called parallels
ude (Plate I., Fig. 2). They are counted from the
which is the zero, or 0°; and each degree is divided
utes and seconds like the degrees of longitude.
we find by observation that a place is situated
egrees north and another twenty degrees south
uator, we say that the one is in Latitude 15°
d the other is 20° South. Each pole is hence
90°. Since the figures expressing the degrees
amount as they recede from the equator, it
common to speak of "low latitudes," that
or places lying towards the equator, and
itudes," that is, tracts situated near either

degrees of latitude and longitude, then, we
s of lines, one running north and south, the
east and west, by which the surface of the
osed to be traversed as by a regular network.
hese lines it is clear that we can fix exactly
positions of places on the earth's surface.
ill determine what is the absolute length
degrees in miles before we can ascertain
es of places and the real area which any
inent, or sea covers. When this is done

when we travel westwards, our watches seem to be going too fast by the same intervals.

8. But this effect of difference of longitude is brought out in by far the most striking manner in the sending of messages by electric telegraph. Though two places may be thousands of miles apart, a word sent from one is almost instantaneously received at the other. When a clerk in London telegraphs at noon to Calcutta (which lies in 88° 30′ E. longitude) his words, though they go with the speed of lightning, arrive about six o'clock in the evening by the clock in India; or should he send a telegram at the same hour to New York, which is situated in 74° W. it will find the clocks there pointing to seven o'clock in the morning.

9. But the determination of the longitude of a place would not be enough. We must be able to tell whereabouts that place lies on its meridian. To do this is what is termed "finding the Latitude." The first thing to strike us in this problem is the fact that we do not require to fix on any arbitrary point from which to begin our reckoning. The axis of the earth gives us two definite points at each pole, and midway between these lies the line of the equator. To determine the latitude of a place, therefore, we have to ascertain how far it lies to the north or south of the equator. Here again we must have recourse to the heavenly bodies.

10. If the axis of the earth were prolonged from the North Pole it would reach a point in the heavens close to the pole-star, called the Celestial Pole, round which in the northern hemisphere the stars, by reason of the earth's rotation, seem to revolve. So that though we cannot measure from the North Pole itself, we can determine our distance from it by observing how much the point of the heavens directly above us (that is, the zenith) is removed from the pole-star or from the celestial pole.

'ound the earth at the equator ; and if it could go through he earth between the poles, it would take about eleven ıys to perform the journey. Upon the surface of a globe such dimensions, the highest mountains and the deepest ːans are far less in proportion than the roughnesses n the rind of an orange.

7. Astronomy has taught us not only the size of our planet but has computed the dimensions of the 's, whence we learn the comparative place of the in the solar system. The planet Jupiter, for ɔle, is 1,400 times the size of the earth. On her hand, our planet is seventeen times larger Mercury, and greatly larger than certain small called Asteroids. Again, the earth is neither to nor furthest removed from the sun ; its mean , as already stated, is computed to be rather an 91 millions of miles. But Mercury, at its distance, is only about 44½ millions of miles m the sun, while Neptune revolves at the mean distance of 2,862 millions of miles. The the great centre of all the movement of the n, would contain 1,400,000 globes as large as

ıg found a means of accurately fixing the ny place on the earth's surface and of deter- ístance of places from each other, men could have been able to carry in their minds but a of the general features of that vast and had they not devised a way of putting ıtures upon paper so as to show their rela- and shapes. Such a delineation of the ırt of the earth's surface is called a Map. he map of any country or continent you d by two sets of lines, one of which, run- ɔp to the bottom of the paper, mark the

we have the materials for estimating the total bulk of our planet and making a correct survey of its surface.

14. Since the lines expressing the meridians of longitude converge to each pole, their distance from each other must vary according to latitude ; the parallels of latitude necessarily diminish in circumference as they recede from the equator. But were the globe a perfectly symmetrical sphere the length of each meridian from equator to pole should be exactly alike, and each of its ninety degrees should be of uniform length. The accurate measurement, therefore, of the length of one of these degrees should give us the means of easily computing the sum of the whole, and thence of ascertaining the true size of the globe.

15. This measurement of a degree of the meridian, as it is called, has been made with great care in different parts of the world. In India the length of a degree was found to be 362,956 English feet, or rather more than 68¾ statute miles ; a degree in Sweden measured 365,744 feet, or, in round numbers, about 69¼ miles. It has been found that besides little irregularities which show that the shape of the planet is slightly distorted, there is a progressive increase in the length of the degrees towards the poles as these two measurements in India and Sweden show. This could only take place by a flattening of the globe at the poles.

16. The sum of all the observations gives for the polar diameter of our globe a length of 7,899·17 statute miles, and for the mean equatorial diameter a length of 7,925·65 statute miles. As the difference is about 26½ miles, each pole must be compressed to the extent of 13¼ miles.

It is not easy at once to grasp the full value of these figures. An express train travelling at the rate of thirty miles an hour would take about a month to go completely

'curately measured with rods or chains as from A to B the figure. Then from A an observation is taken 'h an instrument called a theodolite, to the point C, 'ch may be a hill-top or church tower, or any dis- t object, and the angle C A B is carefully noted. A lar observation is taken at B to determine the angle A. We can now construct our first triangle, and g found by actual measurement the length of its we find by simple calculation the length of its des, and consequently the exact position of C and tance from A and B respectively. From such a ed base a system of triangles is observed all e country, and the true positions of all its main ks are fixed without the necessity of further nent.

V.—A General View of the Earth.

oceed now to take a first general view of the earth with which further acquaintance is to he following lessons. Our progress will pro- nd to be more easy and pleasant, if we can s from the outset such a broad but clear earth as a whole as will enable us to follow references to parts with which we may still

he outer envelope of Air with its winds, d snow, the surface of the globe presents marked, but very irregular divisions of As the result of the surveys and ob- in all parts of the globe, it is ascertained ers nearly three-fourths, and the land one-fourth, of the whole surface of the

degrees of longitude, while the other set, running from side to side, show the parallels of latitude. It is usual in such maps to represent the ground as it might be supposed to appear could we ascend to a great height in the air and take in the whole area at one view, our heads being turned to the north. Hence the top of the map

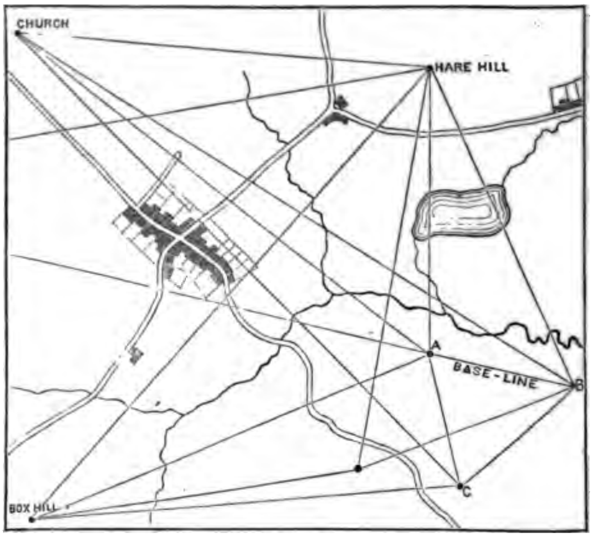


FIG. 6.—Measurement and mapping of a country by means of triangulation.

is north, the right hand being the east side, and the left hand the west.

10. When maps of a country are wanted on a large scale to express the features of the ground in great detail, another process of measurement called triangulation is used. First a base-line, a few miles in length, is

ınd cannot fail to arrest attention at the outset. The nd is much broken up. Even in the Eastern Hemihere, where it presents the most compact mass, long ns and inlets of the sea intersect it, and cut off large tions from the rest. The sea, on the other hand, is lently one continuous whole. Even when penetrating ıest into the land, its most distant arms retain their ection with the main body. A vessel may sail over sea and into every far recess and inlet, without ever ıg to be dragged over an intervening mass of land.) coach or form of carriage could visit every part of d, without requiring to be transported across intertracts of sea. There are no isolated areas of sea ely encircled by land, answering to the abundant of the land which, encircled entirely by sea, receive ? of islands.[1]

ıugh the sea is one continuous liquid mass, it has the sake of convenience in description divided ent areas, termed Oceans. The limits of these e most part indicated by the position of the and. Thus the largest, under the name of the an, fills up the vast area between the western erica, and the eastern margin of Asia and The line of the equator divides it into the : and the South Pacific Ocean. Another longer rrower belt of sea, intervenes between the s of America and the western coasts of frica; divided in the same way by the North Atlantic and the South Atlantic the broad mass of land forming Europe esponding belt of sea can run there from t south of that land lies the wide Indian frica and Australia. It is usual to call

[1] fterwards made to one or two interesting exceptions ın Sea being the chief.

planet; or, more exactly, there are 275 parts of water to 100 parts of land.

3. For the sake of aiding our conceptions of such statements as these, globes and maps are prepared, of which Plate I. may serve as an illustration. Each of the two large circles there represents one side of the earth, and shows the manner in which sea and land are grouped. It will be observed, that while the amount of sea greatly exceeds that of land, the difference becomes more marked in the southern half or hemisphere, which is almost all water, while most of the land lies on the north side of the equator. But a school globe may be so placed, as to show nearly the whole of the land at one view, and the greater part of the sea at another. For this purpose, turn the globe so that the south-west of Britain shall be directly in the centre of the globe as you look at it, as shown in Fig. 3, Plate I. Britain is thus shown to lie in the centre of the habitable globe. Now turn your globe so that the point on the other side, exactly opposite to the south-west of Britain, shall be the centre. The islands of New Zealand are then not far from that position, and all round them lies the water hemisphere with comparatively few detached masses of land (Fig. 4, Plate I.).

4. While the great body of the land lies on the north side of the equator, it will be seen from Plate I. that it forms there two well-marked portions separated by two great tracts of sea. The larger of these portions includes Europe, Asia, and Africa, that is, all the regions which have been longest settled by a human population. Hence it is often spoken of as the Old World. The other portion embraces America, and is called the New World. As the Old World lies to the east and the other to the west, they are commonly described as the Eastern Hemisphere and Western Hemisphere.

5. One difference between the distribution of sea and

the parallel of 45° S. Look, for example, at the way in which the mass of Africa dwindles away southward to the Cape of Good Hope, and how the huge bulk of the Asiatic Continent and its prolongation in Australia apers away to the headlands of Tasmania. Still more emarkable is the attenuation of the American Continent nd its sharpened termination at Cape Horn.

11. Again, not only is the land much intersected by ets, such as the great Mediterranean Sea and the Red , but unlike the sea (Art. 5), large parts are completely off from the main mass, as in Australia, New Zealand, n, Britain, and the host of islands, large and small. r parts nearly isolated are termed peninsulas. Of Africa may be taken as the most conspicuous illus-n. It is joined only by the little connecting neck or us of Suez to the continent of Asia, so that were rip of lowland to be cut through or sunk beneath , Africa would become an island. This, indeed, n in some sense accomplished by man in the of the Suez Canal.

nother feature of the land marks it off in striking from the sea. The surface of the latter, though be roughened by ripples and waves, preserves re the character of one vast level plain. But the the land abounds in unevenness. Some parts, flat, but most of it undulates into hills and l some portions mount up into vast ranges of pointed mountains.

irregular distribution and inequality of surface d a peculiar character and influence in the ography of the earth's surface. Without present how this influence shows itself, we see that if either in the air or in the sea novement of circulation, the currents, both a, must be greatly affected by the position

all that part of the sea within the Arctic Circle the Arctic Ocean, and the corresponding tract in the southern hemisphere, the Southern or Antarctic Ocean.

7. Besides these main sub-divisions, there are minor tracts of sea, more or less surrounded by land. Such names as sea, gulf, strait, channel, are given to them according to their size or the shape of the land-outlines by which they are bounded.

8. The upper surface of the sea forms a sharp, well-marked line, which is called the sea-level. It serves as the line from which the heights of the land and the depths of the oceans are measured. Slight differences of level have been detected between different oceans or seas, as, for instance, between the Atlantic and Pacific, on the two sides of the narrow part of America, and between the Mediterranean and the Red Sea. But such differences never amount to more than a few feet, so that for most practical purposes we may assume the sea-level to be uniform.

9. Passing next to the land, we observe from the map, that while massed on the whole in the northern half of the globe, it is far from forming there one solid block; on the contrary, it is intersected by branches from the sea, so as to be easily grouped into a few great sub-divisions. These are termed Continents. Strictly speaking, there are only two continents, the Old World and the New World (Art. 5). More usually, however, they are grouped in three pairs, the first pair consisting of North and South America, the second of Europe and Africa, and the third of Asia and Australia.

10. Now in considering the general arrangement of the land on the globe, we soon see that one of the most marked general features of the continents is their tendency to get massed together towards the north, and to taper away towards the south to about

CHAPTER II.

AIR.

LESSON VI.—ITS COMPOSITION.

1. Above and around us, to what part soever of the earth's surface we may go, at the top of the highest mountain as well as at the bottom of the deepest mine, we find ourselves surrounded by the invisible ocean of gas and vapour which we call AIR. It must, therefore, wrap the whole planet round as an outer envelope. Considered in this light, it receives the distinctive name of the ATMOSPHERE, that is, the vapour-sphere—the region of clouds, rain, snow, hail, lightning, breezes, and tempests. In the study of the earth as a great habitable globe, this outer encircling ocean of air is the first thing to be considered. What is it? and what purposes does it serve in the general plan of the earth?

2. In early times men regarded the air as one of the elements out of which the world had been made. not so very long since this old notion disappeared. now it is well known that the air is not an element but a compound of two elements—viz., the gases **Nitrogen** and **Oxygen**. It is easy to prove this rning a piece of another element, phosphorus, closed jar. We thereby remove the oxygen,

and form of the continents and islands which may lie in their course. A current in the sea moving westward, for instance, across the middle of the Atlantic, will strike against the long ridge of America, and be turned aside either to right or left, or both. A current of air, on the other hand, if it should take its rise from some centre in the ocean region, will be turned aside when it meets a mass of high land, and may be driven to ascend the slopes, discharge its moisture, and flow on at a much greater height, and at a very different temperature (Lesson X., Art. 31). The varying influence of sea and land upon the air, lies, as we shall see, at the foundation of all the changes of weather.

14. It has been already stated (Lesson III., Art. 4) that at many parts of our planet's surface, pipes or funnels exist, which descending deep into the earth, emit from time to time steam, hot vapours, dust, stones, and melted rock, so as in the end to form conical hills or mountains called volcanoes. It is observed that orifices of this kind are apt to occur in long lines, and especially along the back-bones of the continents, and long chains of islands (see Plate IX.). Over many parts of the globe, too, and particularly in those regions where volcanoes abound, the ground is frequently shaken by earthquakes, and sometimes permanently lifted above its previous level. Such appearances as these afford indications, not only of the nature of the earth's interior, but also of the way in which the interior affects the surface. They help us to understand how it is that the land has been ridged up above the general level of the sea.

15. Into these matters we shall enter more fully in later Lessons. Meanwhile, carrying with us this general outline of the several parts of the earth, we may proceed to consider these parts one by one in detail.

which, when they find a fitting resting-place, lowly forms of plants or animals may spring. Some diseases appear to spread by means of the lodging and growth of these infinitesimal germs in our bodies, for they are so small as to pass with the air into our lungs, and thus to reach our blood.

6. It is difficult to catch these tiny motes from a sunbeam, but rain does this admirably for us. One great office of rain is to wash the air and free it from these impurities. Hence when rain-water is carefully collected, especially in large towns, it is found to contain plenty of these solid particles, which it has brought down with it in its fall through the air. The accompanying drawing, for example, shows what is seen when a small quantity of rain, gathered from an open

FIG. 7.—What is seen after some raindrops collected in a town are evaporated, and the residue is placed below a microscope.

space in a town, is evaporated to dryness, and the residue ie ...ed under a microscope. Abundant particles of soot are mingled with minute crystals of such ... as sulphate of soda and common salt. Hence ...hat, besides the solid particles, there must be ... the air the vapours or minute particles of ...ole substances which are caught up by the rain ... down with it to the soil. In seizing these ...and taking them with it to the ground, the ...s the air and makes it more healthy, while at

which unites with the phosphorus to form a compound substance, and the nitrogen is left behind.[1] In various ways chemists have analysed or decomposed air into its component elements, but the result is always the same, viz., that in every hundred parts of ordinary air there are by weight about seventy-nine of nitrogen and twenty-one of oxygen.

3. Air, when carefully tested, is always found to contain something else than nitrogen and oxygen. Solid particles, with various gases and vapours, are invariably present, but always in exceedingly minute, though most irregular, quantities, when compared with the wonderfully constant proportions of the two chief gases. Some of these additional components of air are not less important than the nitrogen and oxygen. That they exist may be easily proved, and some light may thereby be thrown on the nature and uses of the air.

4. The presence of vast numbers of **solid particles** in the air may be shown by letting a beam of sunlight or of any strong artificial light fall through a hole or chink into a dark room. Thousands of minute motes are then seen driving to and fro across the beam as the movements of the air carry them hither and thither. Such particles are always present in the air, though usually too small to be seen unless when, as in the darkened room, they are made visible against surrounding darkness by the light which they reflect from their surfaces when they cross the path of any strong light-rays. They are quite as abundant in the dark parts of the room, though for want of light falling upon them they are not seen there.

5. Could we intercept these dancing motes and examine them with a strong microscope, we should find them to consist chiefly of little specks of dust. But among them there sometimes occur also minute living germs, from

[1] See Roscoe's *Chemistry Primer*, p. 12.

which, when they find a fitting resting-place, lowly forms of plants or animals may spring. Some diseases appear to spread by means of the lodging and growth of these infinitesimal germs in our bodies, for they are so small as to pass with the air into our lungs, and thus to reach our blood.

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FIG. 7.—What is seen after some raindrops collected in a town are evaporated, and the residue is placed below a microscope.

space in a town, is evaporated to dryness, and the residue is placed under a microscope. Abundant particles of dust or soot are mingled with minute crystals of such substances as sulphate of soda and common salt. Hence we learn that, besides the solid particles, there must be floating in the air the vapours or minute particles of various soluble substances which are caught up by the rain and carried down with it to the soil. In seizing these impurities and taking them with it to the ground, the rain purifies the air and makes it more healthy, while at

the same time it supplies the soil with substances useful to plants.

7. But far more important than these solid ingredients are three invisible substances, two of them gases, called respectively ozone and carbonic acid gas, the third the vapour of water. After a thunder-storm the air may sometimes be perceived to have a peculiar smell, which however is more distinctly given off from an electric machine. This is **ozone**, which is believed to be oxygen gas in a peculiar and very active condition. It promotes the rapid decomposition of decaying animal or vegetable matter, uniting with the noxious gases, and thus disinfecting and purifying the air. It is most abundant where sea-breezes blow, and least in the air of the crowded parts of towns. The healthiness or unhealthiness of the air seems to depend much on the quantity of ozone, which is estimated by the amount of discoloration produced by the air within a certain time upon a piece of paper prepared with starch and iodide of potassium.

8. Consider next the **carbonic acid gas**. When a piece of coal is set on fire it burns away until nothing but a little ash is left behind. Or when a candle is lighted it continues to burn until the whole is consumed. Now, what has become of the original substance of the coal and the candle? It seems to have been completely lost; yet in truth we have not destroyed one atom of it. We have simply, by burning, changed it into another and invisible form, but it is just as really existent as ever. We cannot put it back into the form which it had in the coal and candle, but we can at least show that it is present in the air.

9. The substance of a piece of coal or of a candle is composed of different elements, one of which is called *carbon*. This element forms one of the main ingredients out of which the substance of all plants and animals is

built up. Our own bodies, for example, are in great part made of it. In burning a bit of coal, therefore (which is made of ancient vegetation compressed and altered into stone), or a candle (which is prepared from animal fat), we set free its carbon, which goes off at once to mix with the air. Some of it escapes in the form of little solid particles of soot, as we may show by holding a plate over the candle flame, when the faint column of dark smoke at once begins to deposit these minute flakes of carbon as a black coating of soot on the cool plate. The black smoke issuing from chimneys is another similar illustration of the way in which solid particles are conveyed into the air.

10. But the largest part of the carbon does not go off in smoke. It is in the act of burning seized by the oxygen of the air, with which it enters into chemical combination, forming the invisible carbonic acid gas. It is, indeed, this very chemical union which constitutes what we call burning or combustion. The moment we prevent the flame from getting access of air, it drops down and soon goes out, because the supply of oxygen is cut off.[1] All ordinary burning substances, therefore, furnish carbonic acid gas to the atmosphere.

11. The amount thus supplied is of course comparatively small, for the quantity of vegetable or animal substance burnt either by man or naturally must be but insignificant, when the whole mass of the atmosphere is considered. An infinitely larger quantity is furnished by living air-breathing animals. In breathing we take air into our lungs, where it reaches our blood. A kind of burning goes on there, for the oxygen of the air unites with the carbon of the blood, carbonic acid is produced and comes away with the exhausted air, which we exhale again before taking the next breath. Just as we put out

[1] For some simple experiments on the nature and production of carbonic acid, see Roscoe's *Chemistry Primer*, pp. 3, 5, 14–20.

[illegible] to supply [illegible] surface [illegible]

[illegible] means the [illegible]

[1] The familiar practice [illegible] power of living plants. [illegible] yield a crop of cress, the [illegible] derived not from [illegible] from the [illegible]. See *Kinnard's Chemi*[illegible]

Everyone is familiar with the fact, that when water is heated it passes into vapour, which becomes invisibly dissolved in the air. A vessel of water, for instance, may be placed on a table in the middle of a room, heated by means of a spirit lamp till it boils, and kept boiling till the water is entirely driven off into vapour or evaporated. The air in the room shows no visible change, though it has had all this water-vapour added to it. But it may be easily made to yield back some of the vapour. Let an ice-cold piece of glass, metal, or any other substance be brought into the room. Though perfectly dry before, its surface instantly grows dim and damp. And if it is large and thick enough to require some minutes to get as warm as the air in the room, the dimness or mist on its surface will pass into trickling drops of water. The air of the room is chilled by the cold glass, and gives up some of its moisture. Cold air cannot retain so much dissolved vapour as warm air, so that the capacity of the air for vapour is regulated by its temperature. (See Lesson X.)

16. It is not needful, of course, to boil water in order to get enough of water-vapour in the air of a room to be capable of being caught and shown in this way. In a warm sitting-room, where a few persons are assembled, there is always vapour enough to be made visible on a cold glass. In frosty weather the windows may be found streaming with water inside, which has been taken out of the air by the ice-cold window-panes. Whence came this moisture? It has been for the most part breathed out into the air by the people in the room.

17. Each of us is every moment breathing out water-vapour into the air. As a rule, we do not see it, because the air around us is warm enough to dissolve it at once. But anything which chills our breath will make the vapour visible, such as breathing on a cold piece of glass,

[illegible] 12. [illegible]

13. [illegible]

[illegible] be carbon.

14. Neve[illegible] the air is [illegible] nitrogen an[illegible] more in or[illegible] thousand o[illegible] to support [illegible] earth's [illegible]

15 [illegible]

[illegible] orbit they [illegible]. The light which [illegible] arises from [illegible] the attraction [illegible] atmosphere with an [illegible] by friction [illegible] liberated from the [illegible] them. They soon become [illegible] so intense is the heat to [illegible] that they are dissipated into [illegible] a tail or train of light gradually [illegible]. From the height at which these [illegible], it is inferred that the atmo-[illegible] least 70 to 100 miles above the [illegible] the earth, and may even reach [illegible]

[illegible] these great heights must be very [illegible] from the air next the earth. [illegible] When, for instance, travellers [illegible] said that they find an increas-[illegible] as they advance. In the same [illegible] gone up to great heights in [illegible] and have nearly died [illegible] the air below and that above. [illegible] density, the air getting continu-[illegible] as it recedes from the sea-level [illegible] the difference between the [illegible] we are accustomed next the [illegible] up. Breathing becomes [illegible] than six or seven miles. [illegible] less and less dense, [illegible] at the furthest out-[illegible]

[illegible] space, which is supposed [illegible]

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or metal, when a film of mist at once appears on the object, or walking outside on a very cold frosty day, when the vapour of each breath becomes visible as a little cloud of mist in the air.

18. No matter, therefore, how dry the air may appear to be, more or less of this invisible water-vapour is always diffused through it. Every mist or cloud which gathers in the sky—every shower of rain, snow, or hail, which falls to the ground—every little drop of dew which at nightfall gathers upon the leaves, bears witness to its presence.

19. The importance of this ingredient of the atmosphere in the general plan of our world, can hardly be over-estimated. It is to the vapour of the atmosphere that we owe all the water-circulation of the land—rain, springs, brooks, rivers, lakes—on which the very life of plants and animals depends, and without which, as far as we know, the land would become as barren, silent, and lifeless as the surface of the moon. It is, likewise, to the changes in the supply of this same invisible, but ever present substance, that the rise of winds and storms is largely due (Lesson VII.).

20. The quantity of water-vapour in the air varies from day to day, and, indeed, from hour to hour. It is always comparatively small in amount, ranging from about four to about sixteen parts by weight in 1,000 parts of air.

LESSON VII.—THE HEIGHT OF THE AIR.

1. Though no actual upper limit has been found to the atmosphere corresponding at all to the sharply defined surface of the sea, we cannot suppose that the air extends indefinitely outwards from the earth. The atmospheric

envelope clasps the planet firmly, and moves along with it, both in rotation and revolution. Were this not the case, it is plain that the earth's movement through the air would be far more rapid than the most furious hurricane. No loose object could appear on the surface of the globe without being instantly whisked off. But the attraction of the earth retains the atmosphere in its place, so that it is carried with the rest of the planet through space.

2. There must then be some upper limit to the atmosphere. Beyond it lies the ether, which is supposed to fill all space, and through which all the heavenly bodies, and the rays of light proceeding from them are moving. How can it be known how far the atmosphere extends above us?

3. There are different ways of trying to answer this question. Let us look for a moment at one of them. Most of us have noticed, that on clear, dark nights, shooting-stars or meteors may be seen sometimes in considerable numbers. They suddenly appear, and after making a train or tail of light, quickly vanish. Sometimes they have been actually heard to explode in the sky, and fragments of them have been picked up. They have been carefully watched by astronomers. By observing their positions and directions of movement from, say, two different stations, the distance between which was known, it has been possible to determine how high they are above us, by a process very similar to that by which distances are estimated on the earth by taking angles to any object from the two ends of a measured base-line. They have thus been found to begin to be visible at from 70 to 100 miles from the earth's surface.

4. In themselves they are little fragments, usually not more than a few ounces or a few pounds in weight; but they revolve round the sun with the velocity of planets or

of comets. While still following their usual orbit, they are in themselves cold,[1] opaque bodies. The light which they emit, and by which they become visible, arises from the fact that, drawn out of their course by the attraction of our earth, and rushing into our atmosphere with an enormous velocity, they rapidly get heated by friction against the air, as well as by the heat liberated from the compression of the air in front of them. They soon become white-hot, and in most cases so intense is the heat to which they are raised, that they are dissipated into vapour, which shows as a tail or train of light, gradually fading out of the sky. From the height at which these shooting-stars begin to glow, it is inferred that the atmosphere must extend at least 70 to 100 miles above the general solid surface of the earth, and may even reach further than that.

5. But the air at these great heights must be very different in many respects from the air next the earth. We could not breathe it. When, for instance, travellers ascend lofty mountains, it is said that they find an increasing difficulty in breathing as they advance. In the same way persons who have gone up to great heights in balloons have become insensible, and have nearly died from the difference between the air below and that above. The chief difference is in density, the air getting continually lighter or thinner as it recedes from the sea-level. Our bodies cannot endure the difference between the close, heavy air to which we are accustomed next the earth, and the thinner air further up. Breathing becomes impossible at a greater height than six or seven miles. Beyond that distance the air must get less and less dense, until it reaches an extreme attenuation at the furthest outskirts of the atmosphere.

[1] They probably have nearly the temperature of space, which is supposed to be about 271° Fahr. below the freezing-point of water.

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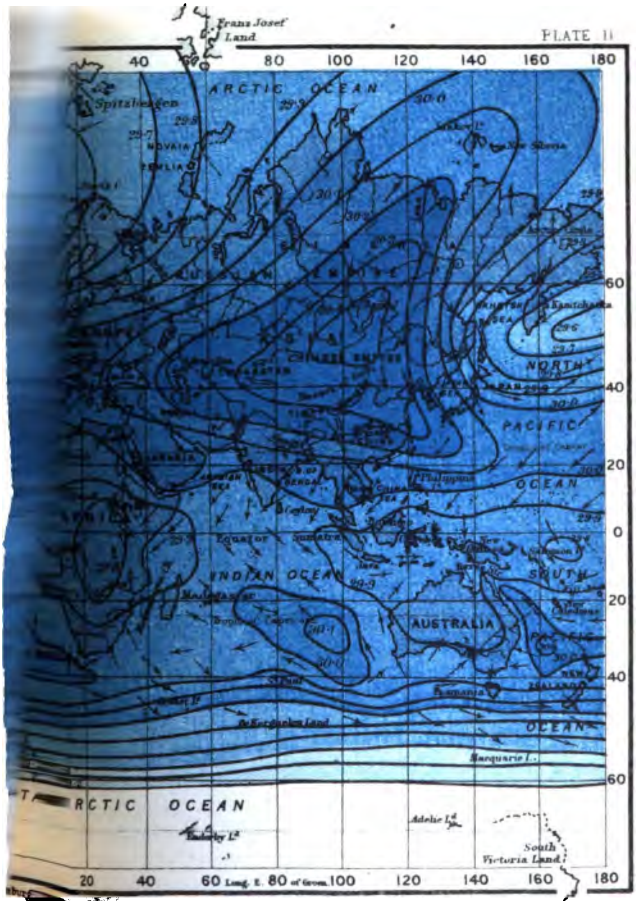
PLATE II



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LESSON VIII.—THE PRESSURE OF THE AIR.

1. Since the atmosphere becomes less dense as it edes from the surface of the solid globe, we see that ugh invisible to us, and so light that we live and ve in it without thinking of its existence, air never-less presses upon every part of the earth. The lower ers in which we live and move, must be pressed down the weight of all the mass of air above them. This is at is usually spoken of as atmospheric pressure. may be due not merely to the weight, but to other pro-rties of the gases and vapours which form the air.

2. To prove its existence, take a little glass phial, and itting it to the mouth, suck out the air as well as pos-ble, taking care to let the tongue press instantly back on the opening. You feel the tongue driven into the ial, and perhaps even with pain, owing to the pressure f the air outside, and the absence of corresponding pres-ure from air inside. An effect of this kind is capable of eing accurately measured. Accordingly, observation hows that, at the sea-level, this pressure is as much as bout $14\frac{3}{4}$ pounds upon every square inch. Every one f us, therefore, bears a weight of 12 or 14 tons of air. Yet e do not feel this pressure, because it is exerted equally n all sides, and because the air within our bodies has the ame pressure outwards which the air outside has inwards. If we could withdraw the air from all the cavities and passages in a human body, the weight of the air outside would crush the body in and cause immediate death.

3. Bearing in mind that each part of the atmosphere has to bear the weight of all the air which lies above it, we can understand why, as we ascend and have a de-creasing mass of air above us (Lesson VII., Art. 5), we should encounter air of less and less density, that is, why

the atmospheric pressure should diminish with altitude. If by any means the amount of pressure at the sea-level can be accurately determined, and at the same time a method can be devised for measuring the rate at which the pressure lessens according to elevation above that level, it will not be difficult to measure the heights of mountains.

4. Now this can really be done by the use of the instrument called the **Barometer**. The principle of this instrument is that the weight of the atmosphere will balance the weight of a column of any other fluid, the height of that column being determined by the relative weight, or what is called the specific gravity of the fluid employed. A glass tube about thirty-three inches long, closed at one end, is filled with mercury, and then inverted with its open end in a cup of the same fluid metal. The mercury is observed to fall in the tube until, if near the sea-level, it stands at a height of about thirty inches above the surface of that in the cup. The column of mercury thirty inches in height is balanced and kept from descending further by the pressure of the overlying column of the atmosphere upon the surface of the mercury in the cup. The more the atmosphere presses upon the latter the further does the mercury rise in the tube, while on the other hand the less it presses, the more the mercury sinks in the tube.

5. With such an instrument, variations in atmospheric pressure may be detected even when so small and slow that we should never otherwise have been sensible of them. If the height of the mercury in the tube is accurately noted at starting, and the barometer is carried to a higher level, the mercury will be observed to fall because of the diminished pressure, while it will rise again when the instrument is brought back to lower ground. So regular and delicate is this action that the barometer

has often been employed for measuring heights. Were there no other cause for variations in the pressure of the atmosphere than merely elevation, the barometer would be most useful for that purpose, but, as we shall immediately see, would be of no service in the way it is now chiefly employed.

6. The diminution of atmospheric pressure according to height in the air is regular and constant. But besides this the pressure is liable to continual changes at every level, sometimes sudden and great, at other times slow and slight. We are made sensible of these variations when they are accompanied by changes of weather. But they are most accurately measured by the movements of the barometer. If from any cause the pressure should decrease, the mercury will fall, should it increase, the mercury will rise, the rapidity or slowness of the movement in the column of mercury affording us, as it were, a mirror of the amount and the rate of change in the balancing atmospheric column.

7. Suppose by way of illustration that on looking at the barometer some morning we should find the mercury to have fallen a whole inch during the night; the mercury column would thus indicate that during a few hours it had lost a thirtieth part of its whole length, and we should be justified in believing that in some way or other the column of air pressing on the mercury in the cup, had in like manner lost a thirtieth part of its pressure or weight. Some of its upper portions must have flowed over into surrounding regions so as to diminish the pressure to such an extent. No such sudden and great change however, could fail to produce a violent hurricane. The fall of the barometer in almost every case occurs in time to prepare us for the coming storm.

8. The barometer tube is divided into inches, and these into tenths and hundredths, so that the position

of the mercury is noted to the hundredth of an inch. When the pressure of the atmosphere just balances a column of mercury thirty inches in height, the barometer is said to mark or stand at 30. If the mercury falls half an inch the barometer stands at 29·50. If it then rises a tenth of an inch it is read as 29·60, a further rise of a hundredth of an inch would make 29·61. The height of the mercury in the barometer at the level of the sea has been found to be very nearly thirty inches as a mean over the whole globe. In different regions, however, the actual average height for the year varies considerably from that mean. In the Pacific Ocean, for instance, some distance to the westward of California, the mercury stands on the average at 30·30 inches. On the other hand, in the north-west of Iceland it stands at a mean height of 29·60 inches, while within the Antarctic circle the average is even considerably lower. When the mercury has fallen below its average height, it indicates a low pressure, when it rises above the average it marks a high pressure.

9. The importance of noting carefully the variations in atmospheric pressure will be apparent from the fact which has now been proved by observation in all parts of the world—that it is differences of pressure which give rise to winds, storms, and in short all the movements of the air which are intimately connected with changes of weather.

But what is the cause of these variations in pressure? Why should the air be liable to such increasing and often sudden, as well as great changes? The only certain answer which can at present be given to these questions is that the pressure is affected, 1st, by temperature, and 2nd, by aqueous vapour.

10. (1) **Temperature.** It is not difficult to see how this influence acts. When air is heated it expands, when *cooled it* contracts, behaving in this respect like other

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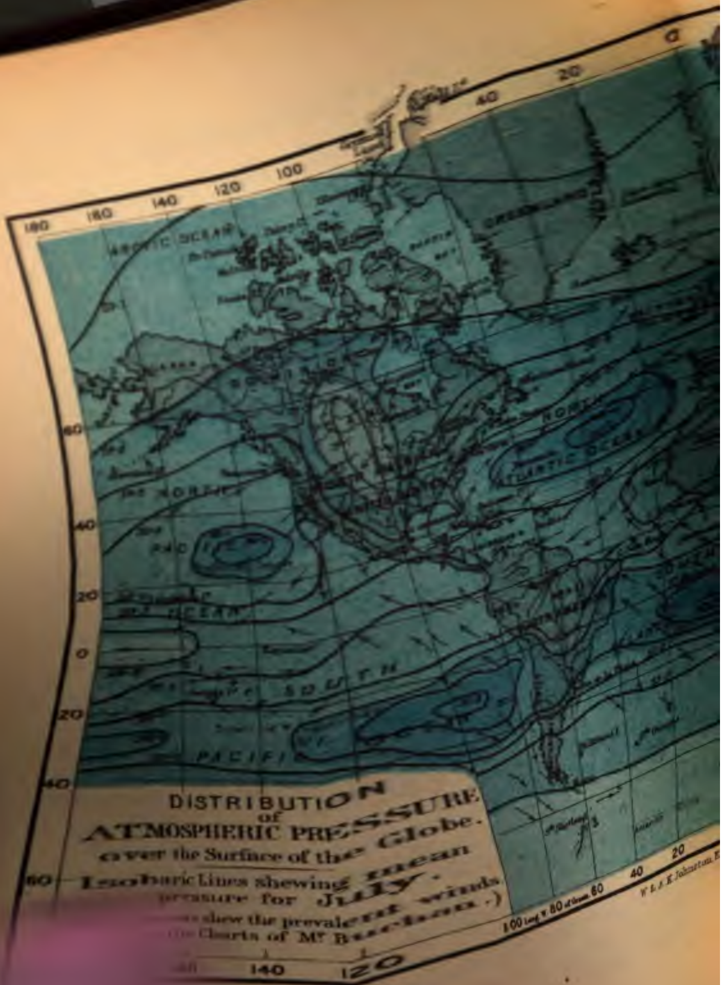
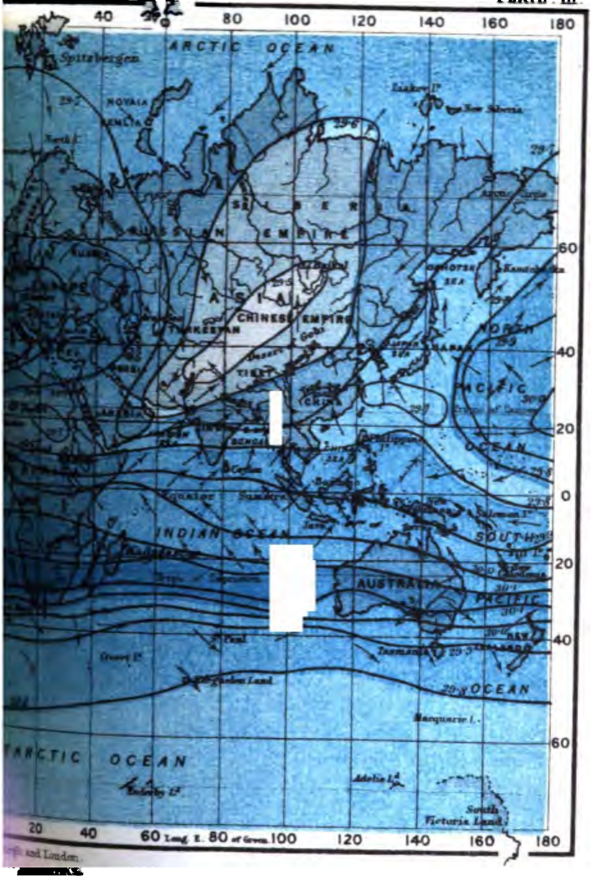

DISTRIBUTION
of
ATMOSPHERIC PRESSURE
over the Surface of the Globe.
Isobaric Lines shewing mean
pressure for July.
shew the prevalent winds
Charts of Mr
ARCTIC OCEAN
GREENLAND
NORTH
ATLANTIC OCEAN
PACIFIC
OCEAN
SOUTH
PACIFIC
W. & A. K. Johnston

PLATE . III.



ARCTIC OCEAN
Spitzbergen
NOVAIA ZEMLIA
SIBERIA
RUSSIAN EMPIRE
ASIA
CHINESE EMPIRE
TURKESTAN
TIBET
CHINA
OKHOTSK SEA
NORTH PACIFIC OCEAN
INDIAN OCEAN
Sumatra
Java
AUSTRALIA
SOUTH PACIFIC
Tasmania
OCEAN
Macquarie I.
South Victoria Land
OCEAN
60 Long. E. 80 of Green. 100
20
40
120
140
160
180

substances. Cold air is therefore denser than warm air, so that the latter ascends, while the former descends. The ascent of warm air must necessarily diminish atmospheric pressure. When a broad tract of the earth's surface, such for instance as the centre of Asia, is greatly heated by the sun's rays, the hot air in contact with the ground rises and flows over into the surrounding regions. Hence the atmospheric pressure there is lowered during the hot months of the year.

11. (2) **Aqueous Vapour** is however found to be a still more important agent in affecting the pressure of the air. We have already considered how universally present this invisible vapour is, and how easily it may usually be made visible by cooling the air; for then the vapour is at once changed into visible water. In Lesson X. an account is given of the vapour of the atmosphere, and the way in which it is continually passing into the air, and as constantly passing out of it again into some visible form of water. Let us consider here how this unceasing process affects the pressure of the atmosphere.

12. *Suppose that we take two empty glass vessels each capable of containing exactly one cubic foot of any substance. By means of an air-pump we remove the air from them as completely as possible; into one of them we admit water-vapour, at a temperature of, say, 50° Fahr. (Lesson IX., Art. 1), till it can contain no more; the other, at precisely the same temperature, we fill with perfectly dry air, that is, air from which the water-vapour has been [illegible]moved as thoroughly as possible. We [illegible]th, and after allowing for the weight [illegible]n each case, we find that the vapour [illegible]rains, while the air weighs as much as [illegible]

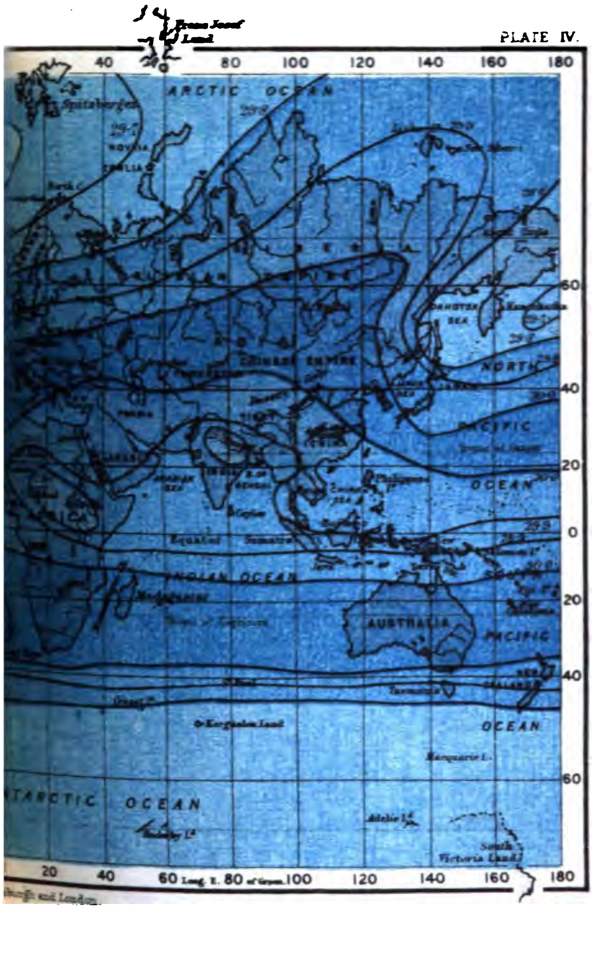
[illegible]ut entering into the question how far [illegible]ure is due to mere weight or to other

tribution of atmospheric pressure over the earth's surface for each month or season, or for the whole year. Plates II., III., and IV., are examples of such charts. It is found that, taking a very broad view of the subject, there are three great areas of low pressure. One extending as a broad belt round the equatorial regions, the other two lying about each pole; and two areas of high pressure extending parallel to the equatorial belt on either side, and separating it from the polar area of low barometer. These areas are most continuous in the southern hemisphere; but even there, and therefore still more in the northern, they are apt to be broken up into detached portions, owing to the irregular distribution of sea and land. They change position too with the seasons, as is well shown by comparing the distribution of pressure in January with that in July, as is done in Plates II. and III.

LESSON IX.—THE TEMPERATURE OF THE AIR.

1. As in the study of the pressure of the air so in that of its temperature, it would not be possible to make much progress without some means of accurately measuring the fluctuations, for it is only the more marked of these of which we are sensible from the comfort or discomfort they bring to us. Happily, in this case, too, the instrument for accurate measurement is exceedingly simple both in its construction and use. It is called the Thermometer, or heat-measure, and consists of a small glass tube closed at both ends, the lower of which is expanded into a bulb. The tube, previously deprived as completely as possible of air, is partially filled with mercury or spirits of wine, and attached to a flat piece of ivory, wood, or other substance, on which is placed a graduated scale. Under the influence of heat the fluid

PLATE IV.


ARCTIC OCEAN
Spitsbergen
Franz Josef Land
CHINESE EMPIRE
PERSIA
INDIA
ARABIAN SEA
Ceylon
Equator
Sumatra
CHINA
Philippine Is.
OKHOTSK SEA
NORTH
PACIFIC
OCEAN
INDIAN OCEAN
Madagascar
AUSTRALIA
PACIFIC
NEW ZEALAND
Tasmania
Kerguelen Land
OCEAN
Macquarie I.
ANTARCTIC OCEAN
Adelie Ld.
South Victoria Land
Long. E. of Green.
20
40
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180

in the tube expands and rises; when the heat is withdrawn it contracts and descends. The temperature is expressed by the figure on the scale of degrees, opposite to which the upper end of the mercury column stands. The thermometer scale used in this country, called after the original maker, Fahrenheit's, is so graduated that when the instrument is placed in melting ice or in water just about to freeze, the mercury marks 32°.[1] This is the *freezing-point* of fresh water. On a pleasant summer day in England, the mercury may mark 70°. On a hot noon in India it would rise to 90° or more, while on the burning sands of an African desert, at the hottest time of the day, it might sometimes stand as high as 150°, or even higher. Under ordinary circumstances the thermometer indicates 212° as the temperature at which water boils. When the mercury is low in the tube, it marks cold, or what is called a low temperature; when it stands high in the tube it indicates heat, or a high temperature.

2. By means of the thermometer it is possible to measure very minute changes of temperature, and to compare the range of temperature in different places. Observations of this kind have now been carried on for many years in all parts of the world, with the result of making known the general distribution of temperature over the globe. To show this distribution it is usual to construct maps on which lines are drawn through all places having the same temperature (see Plates V., VI., and VII). Such lines have received the name of Isothermal lines, or lines of equal temperature. Each of them is named after the degree of the thermometer which it expresses, as, for example, the isotherm of 60°, which shows that all the

[1] The zero (0°) of Fahrenheit's scale is 32° below the freezing-point of fresh water. When the temperature sinks below zero it is marked by prefixing the *minus* sign, thus $-5°$, $-10°$: that is five, ten degrees below the zero-point.

... which it is drawn on the map have the ...

3. ... does the earth receive its heat, and why ... temperature of one part of its surface vary so ... another?

4. ... seen (Lesson III.), our planet ... molten globe, and retains even now ... heat in its interior, its surface tempera- ... thereby. Were it left ... source of heat than its own, its sur- ... so intensely cold as to be utterly ... at least the races of plants and animals ... it.

5. ... the Sun that our supply of heat comes. ... the sun shines brightly, we feel his rays to ... when the sky is clear, we find it cold, ... longer fall upon our part of the ... heat absorbed during the day is given off ... The sun is continually radiating ... mass, and it is according to the ... of this heat which different parts ... earth receive that they vary in temperature.

6. It must be remembered, however, that the air is ... to a very slight extent warmed by the passing through ... of the heat-rays of the sun. No matter how hot ... rays may be felt by us, they do not of them- ... sensibly warm the air. It is when they have heated ... part of the earth's surface that the air resting upon that surface becomes heated by contact with it.

7. The heating power of the sun's rays has been ascertained to be dependent upon the angle at which they reach the surface of our planet. Wherever they fall vertically upon the earth, as at B in Fig. 8, their heating power is greatest. It diminishes as the direction of the rays recedes more and more from the vertical, until, when

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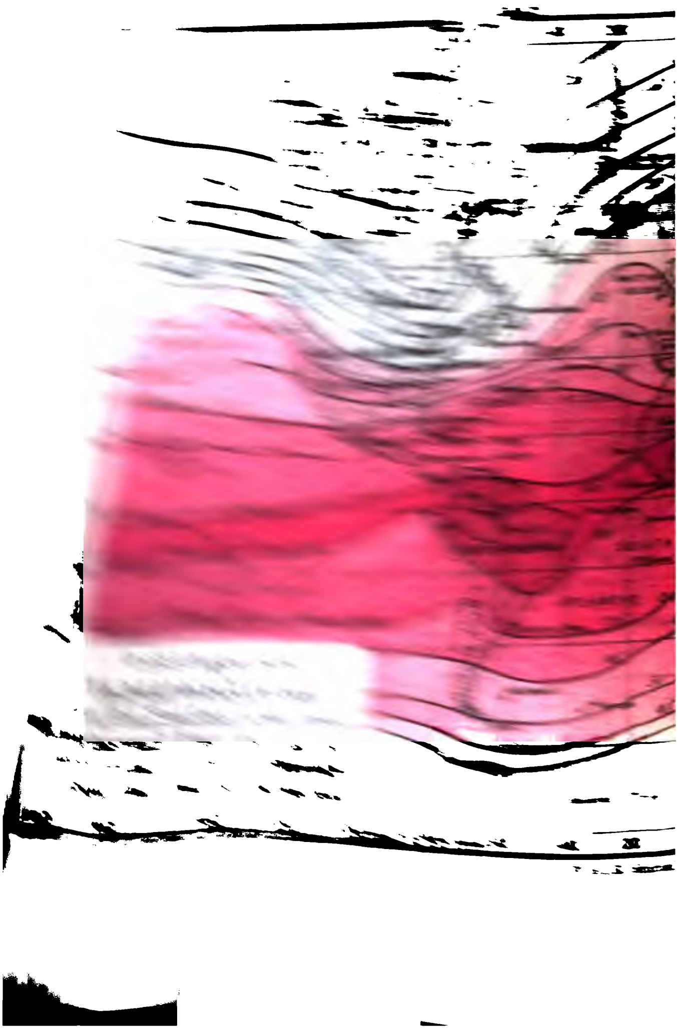
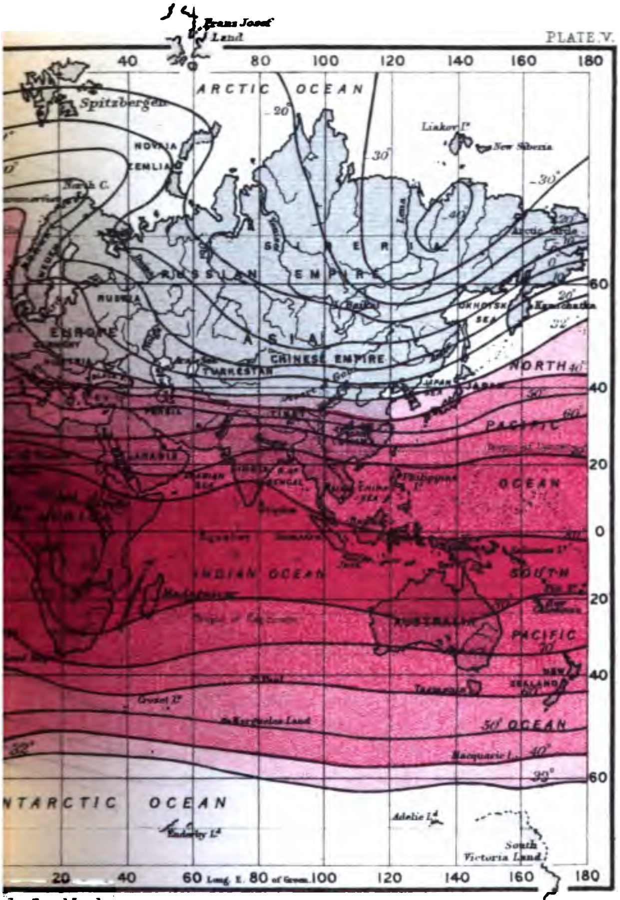


PLATE V.



burgh and London.

they become horizontal, as at A and C, it reaches its lowest point. Hence, though powerful at noon, they are comparatively feeble in the morning and in the evening.

8. In considering, then, the manner in which the temperature of the atmosphere is distributed over the globe, we see at the outset that those countries must necessarily be warmest where the solar rays are vertical or most nearly so, and that those regions must be coldest where the rays are most oblique. Between the tropics (Lesson II., Art. 11,) the sun is vertical twice a year. That belt of the globe must needs therefore have the highest

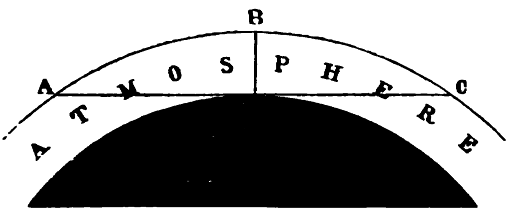


FIG. 8.—Diagram showing the influence of the varying thickness of the atmosphere in retarding the Sun's heat. A. Line of Sun's rays in the morning. B. Line of the rays at noon C. Line of the rays at sunset.

temperature. Round the poles the sun does not shine for six months in winter, and never gets very high in the sky even in summer. These must consequently be the coldest regions. Hence the first conclusion we may draw regarding the temperature of the atmosphere is that it depends upon distance from the equator, or, expressed more shortly, (1) **temperature is regulated by latitude.**

9. If no counteracting influence came into play there would be a regular diminution of temperature from the equator to the poles. Every latitude should then have its own temperature, so that a determination of the

places through which it is drawn on the map have the average temperature of 60°.

3. Whence does the earth receive its heat, and why does the temperature of one part of its surface vary so much from that of another?

4. Although, as we have seen (Lesson III.), our planet was once probably a molten globe, and retains even now a vast amount of heat in its interior, its surface temperature is not materially affected thereby. Were it left without any other source of heat than its own, its surface would become so intensely cold as to be utterly uninhabitable by at least the races of plants and animals which now live upon it.

5. It is from the Sun that our supply of heat comes. At noon, when the sun shines brightly, we feel his rays to be warm. At night, when the sky is clear, we find it cold, because the sun's rays no longer fall upon our part of the earth, and the heat absorbed during the day is given off again into cold space. The sun is continually radiating heat from his glowing mass, and it is according to the greater or less amount of this heat which different parts of the earth receive that they vary in temperature.

6. It must be remembered, however, that the air is only to a very slight extent warmed by the passing through it of the heat-rays of the sun. No matter how hot these rays may be felt by us, they do not of themselves sensibly warm the air. It is when they have heated a part of the earth's surface that the air resting upon that surface becomes heated by contact with it.

7. The heating power of the sun's rays has been ascertained to be dependent upon the angle at which they reach the surface of our planet. Wherever they fall vertically upon the earth, as at B in Fig. 8, their heating power is greatest. It diminishes as the direction of the rays recedes more and more from the vertical, until, when

they show the greatest deflections across North America, the Atlantic, Europe, and Asia. In this way they indicate that temperature is more uniform and more directly dependent on latitude in the oceanic parts of the globe than in the continental, or where the oceanic and continental come together, as they do in the basin of the Atlantic.

13. In order to see the full use and meaning of these isothermal lines, let us take by way of illustration the line in the northern hemisphere marking a mean annual temperature of 50° Fahr. Traced over Britain, this line runs from about London, across the centre of England and the north of Wales: that is to say, all the parts of the country lying along that line have a mean annual temperature of 50°, while the districts to the north-east are a little colder and those to the south-west a little warmer. The line bends south-westward and crosses to the western shores of Ireland. If now we turn to the opposite side of the Atlantic to see where places are to be found having the same average temperature for the year, we do not meet with them on the same parallel of latitude as in the British Islands. They lie much further south, so that the line or isotherm of 50° makes a bend in crossing the ocean, and reaches the American coast not far from New York. The mean annual temperature of London and New York is the same. And yet New York is about as far south from London as Madrid.

14. This isothermal line of 50° between Europe and America and still more the other lines lying to the north of it, illustrate how far the belts of equal heat are from coinciding with the parallels of latitude. It will be seen from the maps how this divergence is determined by the way in which the areas of land and sea are grouped.

15. Land gets sooner heated by the sun's rays than the sea and also gives off its heat again sooner.

sea, though it does not get so hot as the land does, retains its heat longer, and is enabled by virtue of its liquidity and motion to diffuse it. Hence, the influence of the sea tends to mitigate both the heat and the cold of the land. Its warm currents heat the air resting on them, and so give rise to warm winds which blow upon the land, while its colder waters in like manner temper the air, which reaches the land in cooling breezes, or it may be in cold damp winds and fogs. Thus, in the basin of the North Atlantic, a warm ocean-current called the Gulf Stream issues from the Gulf of Mexico, and, augmented by the surface-drift of warm water which is driven onward by the prevalent south-west winds, flows across the Atlantic to the shores of Britain and even of Spitzbergen. It brings with it the supplies of heat which make the climate of the west of Europe so much less cold than it would naturally be. On the other hand, an icy stream of water, coming out of Davis Strait, brings a chill to the coasts of Labrador and Newfoundland. The ocean, therefore, by its cold currents is depressing the temperature in America along the same latitudes where in Europe by its warm currents it is raising it.

16. A large body of land placed in high latitudes by accumulating snow and ice, gives rise to a lower temperature, and a similar mass of land in low latitudes, by exposing a broad surface to the tropical rays of the sun, produces a higher temperature than would be found if the region were occupied by the sea. In illustration of this statement it will be seen from the map (Plate V.) that the January isothermal lines marking temperatures below the freezing-point, come a good way southwards over Northern Asia, and again over Greenland and North America, though in the water passage between these regions they swell a long way northwards. Again, the map of the July temperature (Plate VI.) shows that over

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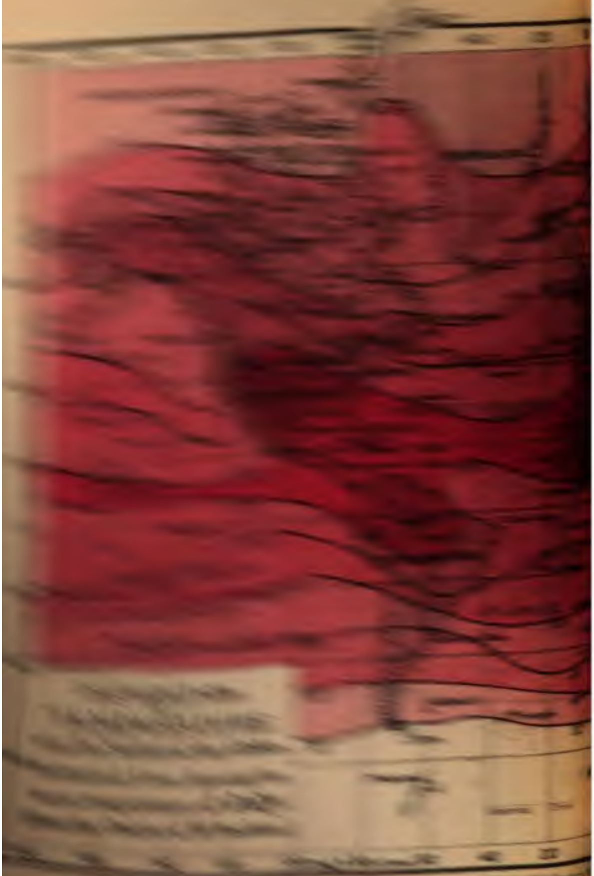

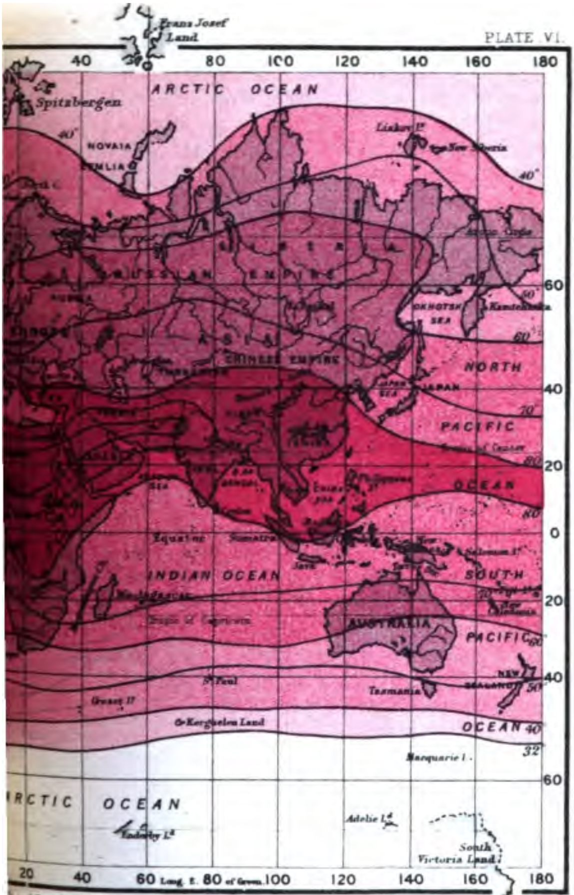
Franz Josef Land
Spitzbergen
ARCTIC OCEAN
NOVAIA ZEMLIA
Liakov Iˢ
New Siberia
RUSSIAN EMPIRE
ASIA
CHINESE EMPIRE
OKHOTSK SEA
Kamtchatka
NORTH
JAPAN
PACIFIC
OCEAN
Equator
Sumatra
Java
INDIAN OCEAN
Madagascar
Tropic of Capricorn
SOUTH
AUSTRALIA
PACIFIC
New Caledonia
Solomon Iˢ
St Paul
Tasmania
NEW ZEALAND
Crozet Iˢ
Kerguelen Land
OCEAN
Macquarie I.
ARCTIC OCEAN
Adelie Lᵈ
Enderby Lᵈ
South Victoria Land
Long. E. 80 of Green.

the equatorial parts of America and the great mass of Africa and Southern Asia, the space inclosed between the isothermal lines of 80° swells out greatly, so as to include a much larger area than where these lines cross the oceans.

17. It by no means follows that two places which have the same average yearly temperature enjoy the same climate. For instance, Reykjavik in the south of Iceland (Lat. 64° 40′ N.), has a mean annual temperature of about 38° Fahr. while the city of Quebec has one of about 40°; but in July the average temperature in the former locality is 51°, in the latter it is 70°; while in the one case the January temperature is 30° and the other 12°; so that in winter Quebec is usually so intensely cold as to have 20° of frost, while the south of Iceland is often without frost. In summer, on the other hand, Quebec is 19° warmer than the south of Iceland. Canada is chilled by the cold land and sea lying to the north and north-east of it. Iceland is warmed by the ocean-current (Art. 15) which summer and winter sweeps past its shores.

18. In order to compare the climates of two places, it is necessary to know how the temperature is distributed through the different seasons. To aid comparisons of this kind, charts are prepared like those in Plates V. and VI., showing the average distribution of temperature for each month, or for summer and winter, as well as charts like Plate VII., constructed to show the mean temperature of each part of the globe for the whole year.

19. From the facts embodied on such charts, gathered as they have been, from all parts of the world, we conclude that (2) **temperature is regulated by the distribution of sea and land.**

20. But there is still another cause on which the temperature of any particular place on the earth's surface is dependent. The two influences already given, viz., latitude

[illegible] sea come into play hori[illegible] [illegible] *vertically.* [illegible] the fact that the air on low-lying [illegible] warmer [illegible] the tops of hills. Even on [illegible] mountains which are comparatively [illegible] summits are so cold that in sheltered [illegible] from the sun and wind snow remains [illegible] throughout the summer. In the [illegible] the Himalaya, the Andes, and [illegible] mountains of the globe the cold is such [illegible] of winter never wholly disappear, but [illegible] as a perpetual covering. There is a gradual [illegible] of the air perceptible as we rise above the sea [illegible] every part of the world. The rate at which this [illegible] temperature takes place varies much, but it is [illegible] taken to be on an average 1° Fahr. for every [illegible] feet. Since within the tropics, while the low lands [illegible] under a burning heat, the mountains, if lofty [illegible] to reach the upper cold air, have their summits [illegible] with snow, we perceive that an elevation of a few [illegible] feet above the sea gives as great a change of [illegible] as a journey of many thousand miles away [illegible] equator would do. So that from these examples [illegible] that [illegible] **temperature is regulated by height above the sea.**

[illegible] the earth is continually receiving such vast [illegible] from the sun, we may be tempted to ask [illegible] warmer. So far as observations [illegible] been made, they do not indicate [illegible] diminution of heat. It would [illegible] back into space as much [illegible] quantity of heat received from [illegible] as remaining on the whole [illegible] careful observations [illegible] the recurrence of

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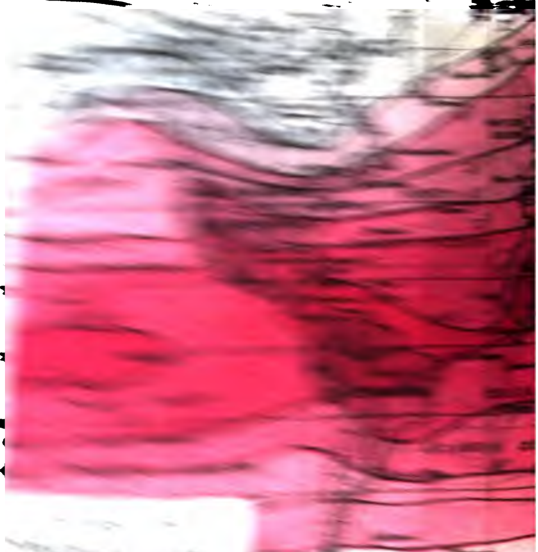
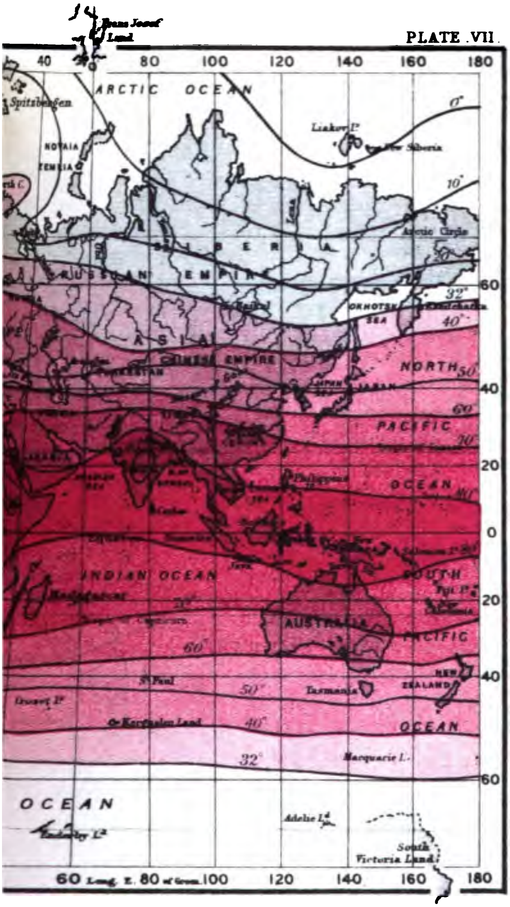


PLATE VII.



Franz Josef Land
ARCTIC OCEAN
Spitzbergen
NOVAIA ZEMLIA
Liakov I.
New Siberia
Lena
Arctic Circle
SIBERIA
RUSSIAN EMPIRE
OKHOTSK SEA
Kamchatka
ASIA
CHINESE EMPIRE
NORTH
JAPAN
PACIFIC
Philippine Is.
OCEAN
INDIAN OCEAN
Java
SOUTH
Fiji Is.
Madagascar
AUSTRALIA
PACIFIC
NEW ZEALAND
St. Paul
Tasmania
Crozet Is.
Kerguelen Land
OCEAN
Macquarie I.
OCEAN
Adelie Ld.
Enderby Ld.
South Victoria Land
0°
10°
20°
32°
40°
50°
60°
70°
80°
60 Long. E. 80 of Green. 100
120
140
160
180

black spots visible there, may yet show that the ıtity varies from time to time, and that the variation ts the temperature and climate of our planet. It been satisfactorily established that there is a coince between heavy rainfall, including storms, and those ds when the sun's face is most marked with spots.

Radiation, or the giving off of heat by the earth, is ıost at night, and especially when the sky is clear. :h times we may learn how rapidly the heat of the passing away from the earth into cold stellar space, ow entirely our globe depends on the sun for its t surface temperature. Objects which in the day 'arm to the touch, now grow more and more chilly. r gets colder by contact with the cooled ground, r own bodies, like everything else around, are at ıe time radiating heat, and adding to our sensation

ESSON X.—THE MOISTURE OF THE AIR.

e of the constantly present ingredients in air d in Lesson VI. was the vapour of water. We nd how important this component is in deterifferences of pressure, and consequently in giving hanges of weather. It may now be considered ›re at length in reference to its sources of supply, ifferent forms in which it is taken out of the air, red again to land and sea.

ɩt then let us ask whence does this widelynd all-important vapour come? It is all evaor given off in an invisible form, from the every sea, lake, river, and spring; in short, from :r-surface on the face of the earth, and even from ow. Nothing is more familiar than the rapidity

...'s heat. But the amount of water which ... the vapour of the atmosphere is best ... we consider the enormous quantity dis... the sea by rivers. All over the world, ... and small, are continually pouring their ...ater into the ocean. All that water was ...n the atmosphere to them either directly by ...ows, or indirectly by springs. But they ob...nally even more than that vast quantity which ...rge, for while they are coursing down from the ... to the sea, vapour is continually rising from ...ces and their volume is consequently growing

...nen, from every ocean, lake, and river on the ... the globe water-vapour is continually passing ... air, what becomes of all this vapour, and why do ... waters of the globe grow less? The reason is, ... conversion of water from its common visible ...rm into the invisible gaseous state is only one ... gigantic system of circulation. The vapour is ...wed to accumulate indefinitely in the atmo... it is changed back again or condensed into ...d then appears in such forms as dew, clouds, ...now.

... two processes of evaporation and condensation ...he whole to balance each other; that is, so far as ... features of the earth's system are concerned, ...ears to be about as much water returned to the sea ... as is taken from them by the atmosphere. It is ... circulation of water that all the manifold pheno... ...ouds, rain, snow, rivers, glaciers, and lakes arise. ...han this, if we reflect that now evaporation and ...nsation must from time to time be predominant ...ice, we perceive how greatly these processes ... the pressure of the air; and since variations

is not sensible so long as the vapour remains uncon-
ed, and it is therefore termed *latent*.

When, on the other hand, condensation goes on, eat which the vapour had held in its grasp is given gain and becomes *sensible*, as the vapour passes into . It has been pointed out, for example, that every l of water which is condensed from vapour liberates enough to melt five pounds of cast iron. We can nderstand, therefore, that when the process of con- ion takes place in nature on a large scale, the sion of vapour back again into the state of water ally warms the air.

The act of condensation always occurs when air is down to its *dew-point* (Art. 14); but this does not happen at the same temperature, nor does it appear same forms. Sometimes it issues in a light mist, s of dew, or drops of rain, or, if the temperature be low enough, in flakes of snow or pellets of hail. he substance which we call water is thus shown in three forms, according to temperature. At temperatures, or from 32° to 212° Fahr., it is t as a *liquid*, and this is, of course, its most condition. If at any temperature, it is allowed exposed to the air, or if by having its tem- raised to 212°, it boils, it passes off into invisible If again the temperature be depressed to 32°, begins to become *solid*. It crystallizes into the lourless substance called ice. This act of crys- has received the name of *freezing*, and the re (32°) at which it takes place, is called the *oint*. According, therefore, to the temperature condensation takes place, the vapour is made ssume a liquid or a solid form.

.—On a summer evening, if the sky is clear, con- akes place on the leaves of plants, on stones and

[illegible]

› *space* while they themselves radiate heat towards earth; hence it is that cloudy nights are warmer than ›e which are clear and starry.

8. Mist and Fog.—When a mass of warm and moist meets colder air, or comes in contact with cold ınd or in any other way is cooled down below its ·point, the excess of vapour which it can no longer n condenses into minute particles, and is made le in the form of Mist or Fog. In winter we a familiar illustration of this phenomenon in the ›nsation of our breath into mist as it passes from the h into the cold air. In summer, mists frequently in the evening over rivers and sheets of still water. liation goes on, the ground round the water becomes ıl degrees colder than the water itself, and the r rising from the water is consequently chilled by r and condensed into banks or sheets of fog. Again, a warm wind strikes upon a hill or mountain, and is to ascend the slopes, its temperature begins to fall, this cooling is carried below the temperature above it can retain its vapour, that is its dew-point, the of vapour takes the form of a mist.

Clouds.—Dew and mist are formed on or near ound, whether low plains or high mountains. ıenever the vapour is carried up into the cold ›arts of the atmosphere, it there becomes visible ıer form of condensation as Clouds. A cloud a mist hanging in the air instead of resting ;round. When the ground rises into the upper does in mountains, it reaches or even surmounts 's of the atmosphere where clouds are commonly We see wreaths of cloud gathering on the sides its of mountains, and yet if we climb up to these › find them to be mere masses of mist, such as are ›wn among the valleys.

een, and at last when night sets in, the sky is once clear and cloudless. In such cases, it is to the ing of the earth by the sun during the day, and the quent ascent of moist air-currents, that the clouds e. Each growing mass of cloud forms the top or , as it were, of a column of up-streaming warm air vith vapour. The air, expanding and cooling as it last reaches a point where it can no longer retain ur, and there the cloud begins to form. But after of the day is over and the warm moist air no treams upward, the cloud ceases to grow larger. begins to sink earthwards, as radiation goes on, ng into warmer air, it gradually melts away so as ie sky clear and starry.

the atmosphere is traversed in all directions ts of air of various temperatures and de- noisture, the meeting of these currents must rise to clouds, and also melt clouds already warm moist wind, for example, coming in con- cold wind will part with some of the vapour as he other hand, when a belt of cloud is invaded air, it will be evaporated and disappear. As which are ascending in the air, increase in et higher, while those which are descending ecause the air in which they are suspended n the one case, and warmed in the other. inual movements of the atmosphere, which never-ending comings and goings of the ove us.

louds get into one of the upper steady y are borne along sometimes for great t a great rate. On a breezy spring day en sailing across the sky at what may pace, which, however, is proved to be n eighty or ninety miles an hour by

mist, which, seen from a distance, takes of a cloud capping the summit. This cloud ary, but the little particles of which it consists The wind continues to blow up and over untain-top, and the vapour which it carries made visible as mist or cloud, while it sweeps chill ground. When it has passed the mountain es again with the warmer air beyond, the visible redissolved, and the cloud therefore melts away eward side of the hill as fast, perhaps, as it formed indward side. The cloudlets, too, which are occaletached and carried away from the mountain-top wind, are gradually absorbed into the air again isappear (Fig. 9.)

onsiderable variety exists in the forms which sume, from the thin flaky cloudlets seen in the r air down to the huge rolling rain-clouds which n low upon the hills, and the dull grey sheet of h sometimes overspreads the whole sky. To us forms special names have been given which, is not necessary to enumerate here. Each ud is formed in particular conditions of the and hence a study of the clouds furnishes ormation regarding the weather. This subject ongs to the study of Meteorology.

hief function which has to be considered in sm of the clouds is the way in which they rth with moisture. The vast amount of water e atmosphere as invisible vapour returns to f the earth again to feed the springs and land and to replenish the sea. In this llation the clouds act the part of con- collect in a visible form the ever-present of the air, and allow it to fall back again

26. Rain.—By far the larger part of the vapour of the atmosphere descends to the earth in the form of rain. The little water-particles of which cloud is composed run together as the condensation proceeds. As the drops thus formed increase, they become too heavy to float in the air, and begin to fall earthwards as rain. At first they are very small, as we may feel if we happen to be on a mountain where the mists are gathering into rain-clouds. But as they descend through the air they increase in size until they reach the ground in well-marked rain-drops.

27. Rain, therefore, is a further stage in the condensation of mist or cloud. If the chilling of the cloud is prolonged, rain falls from it. This may be caused in several ways. For instance, where a warm moisture-laden wind comes against a range of high mountains, and is consequently forced to ascend, it may not only be condensed into mist (Art. 19), but if cooled still more, will drop its moisture as rain. Or a cold wind which is heavy and keeps next to the ground, may wedge itself in below a warm, moist layer of air, and so chill it as to form cloud and bring down rain.

28. The fall of rain being dependent upon the amount of evaporation is greatest in tropical regions, where the largest quantity of vapour passes up into the air, and diminishes with the gradual sinking of the temperature towards the poles. But this general law is subject to some important qualifications by the distribution of sea and land, and by the direction of the great aërial currents.

29. (1.) Although evaporation is more abundant from the surface of the sea than of the land, condensation is more active over land than over sea. Hence the rainfall is also greater over land than sea, and over the northern hemisphere, much of which is land, than over the southern hemisphere, most of which is water.

(2.) As the ocean furnishes most of the vapour of the tmosphere, the condensation of vapour into rain upon ie land is greatest near the coast-line. The sea-board a country may be rainy while the interior is compara- 'ely dry.

3.) The fall of rain is greatly affected by the form of surface of the land. Mountains act as condensers t. 23), and are consequently much wetter than ns.

.) Places which lie in the path of any of the regular urrents are wet when they cool the current, and dry ı they warm it. Hence winds blowing towards the tor, since they come into warmer latitudes, are not ly wet winds; but when they blow towards the they reach colder latitudes, and are chilled and ore rainy.

Some of these laws are well illustrated in the Islands, where the rains are chiefly brought by ith-westerly winds which have come across the c. The coast-line facing that ocean is more han the east side looking to the narrow North n the former part of the country away from the e amount of rain which falls in a year would, if together, have a depth of from thirty to forty-five however, the average annual enty to twenty-eight inches. appens to be mountainous, an he wetness of the climate along otland and in the lake district -fall ranges from eighty ies even more than

at different points mount of rainfall. rmous evaporation

ɩ, u
dr
ed
ɪr

which there takes place raises a constant stream of vapour into the atmosphere, rain is heavy and frequent, so much so that this belt of the earth's surface is known as the Zone of Constant Precipitation (Lesson XI., Arts. 10, 11). When in this rainy region a high mass of land lies in the path of the warm moist air-currents, the rainfall is still further increased. Thus in India the range of the Khasi hills stretches across the course taken by the winds called the south-west monsoons, which bring up their burden of warm vapour from the Bay of Bengal (Lesson XI., Art. 34). The result is that the winds as they slant up the hills into the higher and cooler air have their moisture at once precipitated as rain, of which as much as from 500 to 600 inches fall there in the year.

32. Again, a tract of country situated behind a high mass of land to which vapour-laden winds blow, may have little or no rain. Thus in India, while the range of the Western Ghats, lying in the pathway of the warm moist monsoon from the Indian Ocean, intercepts a heavy rainfall, amounting on the tops of the range to 260 inches annually, the country on the east or lee side receives comparatively little rain. Puna for instance, lying at the foot of the hills, has a yearly rainfall of only 26½ inches.

33. In South America the high chain of the Andes takes out the last of the moisture which blows from the east across the Continent, and the winds descend upon Peru so dry that rain is almost unknown there. Another and much greater rainless tract is seen in the desert regions from North Africa across Arabia and far into the heart of Asia. In these parts of the earth's surface, the dry, sandy soil is raised to an intense heat during the day. There is little or no water to evaporate. The hot, dry air ascends, but the winds which blow in upon the *deserts* cannot deposit any moisture, for instead of being

ed, they are heated and driven up in the ascending
ents.

I. In some countries (Lesson XI., Art. 21) the wind
s for part of the year in one direction, and for the
n the opposite direction. These periodical winds are
ally accompanied with rain when they come from
to colder regions, and with dry weather when
come *from* a cooler to a warmer climate. In such
s there are consequently rainy seasons and dry
s. During June and July, for example, the
rly wind, referred to in Art. 31, brings the "rains"
fresh the surface of India after the scorching heat
il and May. During November, December, and
r, on the other hand, a cool dry wind gently
s *down* from the northern mountains into the
of Hindostan, and brings calm dry and settled
. In *north*-western Europe, and generally in
rts of the earth which lie in temperate and arctic
great *irregularity* of rainfall occurs. At the
autumn the weather begins to get more rainy,
tinues so during the winter until spring. But
inued and heavy rains occur also sometimes in

to the earth as water nearly pure. It
al distilled water. But nevertheless it
er quite pure, and sometimes it contains
nount of impurities. These have been
to in Lesson V. Thus it absorbs a little
cids, and some gases and
minute quantity in the air.
arth, together with floating
quantities in the air. The
furnishes a large supply of
nic matter, while over and
croscopic living organisms

[illegible]

96. Snow.—When from any cause, and in any place, whether on the land, on the sea, or in the air, water is cooled down to 32° Fahr., it usually no longer remains in the liquid form, but passes into ice (Art. 15).

Ice is formed in the air by the freezing of the particles which are condensed from the water-vapour. It may descend to the ground as Snow, Sleet, or Hail, according to the circumstances in which it is formed or the condition of the successive layers of air through which it has to pass in its descent. Since the temperature falls in proportion as the air recedes from the surface of the earth, the freezing point will be reached at no great height above the ground. We might, indeed, imagine a line drawn through the air above our heads, from pole to pole, marking the isotherm of 32°, that is, the limit above which the water-vapour must condense into ice, and below which it will condense into water. Such a line would be constantly moving up and down, according to the [illegible] and the varying currents [illegible]ice, it would descend to [illegible] the ponds and streams [illegible] period, called a frost,

ıile in summer it would be a mile and a half above r heads. In India it would be three miles overhead.

ɪ7. Let us imagine, then, such a variable line or limit the air, and consider the forms in which the frozen isture exists there, or descends thence to the ground. s highly probable that many of the delicate white ıdlets which we see far up in the air in summer are le of fine snow. At a lower level, flakes of snow are ıed and fall earthwards, though from their feathery ıs and lightness they are liable to be driven about by y feeble breath of wind.

ɪ. If you look at a snow-flake formed in calm air, find that it has a regular structure, that in fact it is up of minute needles or crystals of ice symmetrically ıged. These are grouped into a star with six rays,

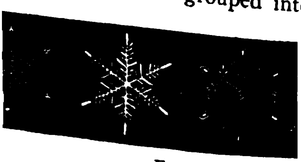


FIG. 10.—Snow-flakes.

of which has a feathery surface, from the abundance nute crystals of ice ranged along its sides. The panyin 'cut represents different varieties of lake ill e seen that they are only modi- ns six- ayed star. The rays strike off ac n angle of 60°, and no matter how c of the snow-flake may be, you will h maintained between all sheets which form on er of cold climates, o range themselves in nly in the snow-flake

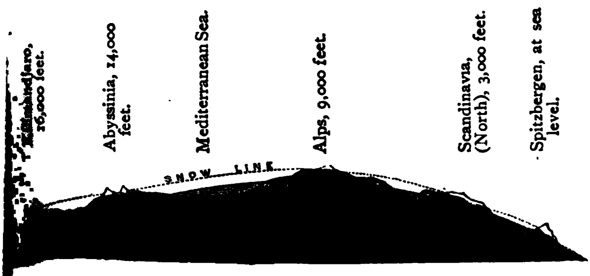
[LESS.

[illegible] be taken
[illegible] crystal or
[illegible] with the
[illegible] mass of
[illegible] colours
[illegible] surfaces
[illegible] white,
[illegible] is made
[illegible]
[illegible] much below
[illegible] appears
[illegible] powder. The
[illegible] at the
[illegible] place
[illegible] This rises
[illegible] colder
[illegible] so that when
[illegible] dry.
[illegible] snow
[illegible] isothermal
[illegible] near
[illegible] those
[illegible] Again,
[illegible] moisture
[illegible] Thus the Hima-
[illegible] hottest
[illegible] upper
[illegible] are there-
[illegible] high
[illegible] feet
[illegible] north
[illegible] into

[illegible] the usual
[illegible] and [illegible]

snow the moisture which is blown from the Indian Ocean and allow the air to pass comparatively dry over to the north side, and because the dry air from the heated plains of Thibet evaporates the snow on the north side.

42. The snow-line, or limit of perpetual snow, is the name given to a line below which the summer heat suffices to melt all the snow, but above which more snow falls than the warmth of the summer months can thaw (Fig. 11.) We may picture it to ourselves as a great invisible arch, of which the centre rises high over the equatorial regions while the extremities come down to the sea-level within the Arctic and Antarctic circles. Under the centre of



·ion and h· Snow-line between Equatorial Africa Polar Seas.

he temp so high that snow is only seen ftiest n about a height of 15,000 to ·et over ·l, while towards the north and where th ure is ·tly lower, the snow as not w· ·l, ev to the margin of

Snow ·t use r, as it protects ·n f ·ipped · frost. Being a ·du· , it ke ·l and plants on ·it ting r ·i their warmth.

During a frost, therefore, the soil and the plants under a few inches of snow will be found soft and uninjured, while on those places where the snow has been blown away the soil is frozen stiff, sometimes to a depth of eighteen inches.

44. When snow accumulates above the snow-line it gets pressed into ice, and creeps down into the valleys in the form of Glaciers. But this further stage in the history of snow will be considered in a later Lesson when we come to look at the circulation of water over the land.

45. Sleet.—When snow is much driven about by the wind its delicate fretwork of crystals is greatly broken. If this takes place when the temperature is rising, or if the driving snow falls through a warmer layer of air, it begins to melt, and in this half-melted state reaches the ground as sleet.

46. Hail is the name given to pellets of snow and pieces or concretions of ice which fall from clouds. Usually hail-stones are small, white, rounded, conical, or irregular. Sometimes, though rarely, they assume more definite crystalline shapes. They are occasionally as large as eggs, and sometimes, when several of these come together in their descent through the air, they freeze into large irregular lumps of ice, and in that form reach the ground. Hail is more frequent in summer than in winter, and in hot than in cool weather. It is generally supposed to be caused by the contact of cold currents of air with warm wet ones, though we do not yet quite know how this change takes place. Hail frequently accompanies thunderstorms, and is thus connected with electrical changes in the atmosphere.

47. Hailstorms are sometimes remarkably destructive. When the fragments which fall are of large size they break branches from trees, destroy growing crops, maim and kill cattle and human beings, and injure

buildings; the course of one of these storms can thus be traced across a country by the devastation which it leaves behind it.

Lesson XI.—The Movements of the Air.

1. How rarely does the air seem to be perfectly motionless! Even when we say that "not a leaf is stirring," that "the cottage-smoke mounts up straight," or that "the clouds are at rest," we can find, if we look for it, proof enough that the air is not so stagnant as it seems, but is ever moving and mixing. Usually the motion is easily recognised, sometimes in a mere light air or in a gentle breeze, or a strong wind, or a boisterous gale, or, it may be, in a destructive tempest.

2. Why should the air be so restless? We have already found the answer to this question: because, owing to the unequal heating of the earth's surface by the sun, and the ever-varying amount of water-vapour poured into or withdrawn from the air, the density or pressure of the atmosphere never remains long stationary at any one place. All movements of the air arise out of differences of pressure. The law governing the direction of these movements may be stated thus, *air always flows in spirally from areas of high pressure into areas of low pressure.* That this must be their direction will be apparent if we reflect that low pressure indicates a deficiency, and high pressure a surplus of atmosphere. The column of air is heavier in the latter case than in the former. Consequently, obeying the universal law of gravitation, the heavier column must necessarily flow out at the base to supply the deficiency in the lighter one. The air does not flow from all sides straight into a low-pressure area.

It circles round it, but always getting nearer to the centre, until it is drawn up and passes away into higher regions of the atmosphere. This inward circling of the air is termed a *cyclone* or cyclonic movement; while the outward flowing from a region of high pressure is called an *anticyclone* or anticyclonic movement. The rate of motion of the air is usually much higher in the former than in the latter. Storms of wind and rain are associated with cyclones; while calm air or light breezes accompany anticyclones.

3. We are accustomed to think only of the horizontal movement of the wind along the surface of the earth. But to form a proper idea of the circulation of the air, we must look upon that horizontal movement as only one part of a much wider system of change. Each cyclone or area of low pressure has at its centre an ascending current, and each anticyclone or area of high pressure has a descending current of air, and it is the position and extent of these upward and downward currents which govern the direction of the winds at the surface.

4. The rate of motion of the surface-currents or winds must evidently be determined in each case mainly by the amount of difference in the pressure and the distance between the centres of the two areas of higher and lower pressure. The greater that difference and the shorter the distance within which it occurs the more rapid will be the flow of air. This is referred to again in connection with ...ns in Arts. 24—29.

It will occur to you, then, that if there be this constant ...n between atmospheric pressure and atmospheric ...nent, it is only needful to know how one of these is ...uted over the globe to have a good understanding of ... must be the distribution of the other. This is really ... If we kn... ...e average readings of the barometer ...a con... ...the whole surface of the globe

for any given period, we can readily tell what must be the direction of the chief aërial movements at any particular place. Plates II., III. and IV., illustrate this relation between the distribution of atmospheric pressure over the globe and the general circulation of the atmosphere.

6. The principal causes of differences in atmospheric pressure were stated in Lesson VIII., Art. 18, to be temperature and water-vapour. It is not always possible to say how far any particular movement of the air is due to the one or the other of these causes, or to both combined. Directly or indirectly, indeed, everything might be referred to temperature, for evidently the process of evaporation on which the addition of water-vapour to the air depends is really regulated by temperature, being greatest when the temperature is high, and least when it is low. But it is useful to distinguish between the effect produced by the mere heating and cooling of the air and that due to the changes in the amount and distribution of its vapour.

7. Let us take some simple illustrations of the influence of temperature in producing movements in the air. A fire, whether in a room or out of doors, furnishes an excellent example on a small scale of what takes place in nature. When a fire is kindled in a grate the air overlying it is heated, and ascends; but at the same time there is an in-draught of air at the bottom of the grate. A circulation is established. The air from all parts of the room and from outside, through the crevices of the doors and windows, is drawn towards the fire, warmed, and driven up the chimney. If in any way this free circulation is interrupted, the fire does not burn well, while if it is stopped, the fire goes out. Again, when a house or any large building, or a prairie or forest, takes fire, the heat may be so great as to cause a very rapid ascent of a considerable mass of air above the burning materials. This

is necessarily accompanied by a flow of air inwards from all sides along the ground towards the fire as a centre, and this in-draught may be sometimes such as to amount even to a violent wind. Rushing round towards the blazing centre, this wind feeds the flames, and, as it gets heated, ascends with great force, carrying clouds of smoke, sparks, and even, it may be, large fragments of burning wood along with it.

8. The heat of the sun is not concentrated upon a limited spot like a burning building or even a wide forest on fire. But the heating of a mass of land during the day produces effects quite similar in kind to those we have just been considering, wherever the heated land lies near some other area (of water, for example) which has not been heated so much.

Nowhere can this be seen to more advantage than in the maritime districts of countries where the days are warm and the nights cool. During the day the surface of land becomes much warmer under the sun's rays than the sea does, and the air resting on that surface becomes hotter than that resting upon the sea. The result of this difference of temperature (and therefore of pressure) is to set in motion a light breeze, which, increasing in force during the day, moves from the sea to the land, in order to take the place of the hot air which is always streaming up from the heated surface of the land. This is a sea-breeze. It dies away in the evening. When the nightly radiation begins, however, the land parts with its heat more readily than the sea does, and consequently cools the air more. The air over the land, being denser than that over the sea, moves seaward to take the place of the ascending current from the sea, and hence arises a land-breeze. This movement in turn increases in force, as the difference of temperature between sea and land is *augmented* by the continued radiation, till it may rise to

a good stiff breeze, which, however, dies away before morning, when the sun once more begins to take effect upon the land, and the temperature of land and sea again becomes uniform.

In mountainous countries where the higher ground rises far up into the colder layers of the atmosphere, another beautiful illustration of these changes of movement in the air may be watched. During the day the air, warmed on the mountain-sides, ascends, and a breeze blows up the valleys towards the heights. During the night the cold heavy air on the mountains flows down as a cool breeze into the valleys.

9. As regards the water-vapour in the atmosphere and its effects, let us consider where these should be looked for in their greatest intensity. Evidently they must be most marked where the temperature is greatest. Hence the broad belt of low atmospheric pressure between the tropics (Lesson VIII., Art. 19), should be the part of the earth's surface where this feature in the motions of the air is best studied. There the sun's heat is greatest and the evaporation greatest. The tropical belt, indeed, with its wide ocean surfaces, may be looked upon as the great evaporating cauldron of the globe, whence comes most of the moisture which is distributed by the winds as rain and snow. It is necessarily a region of low pressure, and therefore air, from north to south, must be constantly pouring into it. Were there no interrupting masses of land the regularity of this movement would be continuous all round the globe. A constant
vould blow towards the equator from either side,
tween the two opposite currents there would be
which the currents would meet and ascend as
reaming mass of air along the centre of the tract
ressure. The position of this zone would vary
g to the position of the sun. In July it would b-

Thence fol- … would travel … and to the Tropic

… land and water, … covered with. It is … where there is … than in … lies nearly … sea in its track … of the equator … the continents

… these irregularities, … belt of the globe … volume of water- … influx of vapour, … along that belt, … humid air into … and a consequent … It is called the Belt … misleading name, … winds, the air … and streams

…rents.—The hot … belt ex- … parts with … falls as rain. … great heat, … and thun- … stant … higher … divides, … and each

ın upper current taking a direction exactly opposite hat of the in-draught at the surface. These upper ents must be many thousand feet above the sea at the torial belt. They travel pole-wards until reaching elt of high pressure they descend and at last reach ırface in temperate latitudes. Thence the air streams back along the surface to the equator and partly ds the pole.

Here, then, we have the fundamental aërial circula- the globe—a great system of surface currents con- streaming out of the bands of high atmospheric e towards the belt of low pressure round the on the one side and towards the poles on the nd of upper currents constantly flowing away from pressure areas—a system set in motion by the varming of the equatorial regions by the sun, and ter moisture and consequent lower pressure of sphere there than in the regions on either side. might be supposed that these currents flowing rrupted circulation should have a direct north course. And so they would, were it not that instead of being at rest, is always rotating on

ing to th f rotation, an object
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it carries with it part of its equatorial rapidity of rotation, and goes a little faster than the surfaces over which it successively moves. Now, as the earth rotates from west to east, all the air which is trying to flow straight from the equator towards the pole is bent slightly to the east. On the other hand, as the air which travels from higher latitudes towards the equator is always getting into regions where the speed of rotation increases, it seems to lag behind, and instead of flowing straight north and south, it is deflected towards the west.

14. The lower or surface currents, turned more and more westwards as they advance, become on the north side of the equatorial belt the North-east Trade-winds, and on the south side the South-east Trade-winds. These are constant winds. They always stream towards the equator because of the lower atmospheric pressure there. They received the name of "Trade-winds" in the early days of navigation, when it was found that they blew so steadily in one direction that they could always be reckoned on for the purposes of commerce.

The Trade-winds are chiefly felt between each tropic and the equator, but they begin in some places considerably beyond the tropics, their constancy being better exhibited over the oceans than over the land, seeing that the more marked heating and cooling of the land by day and night tend to disturb their regularity. Beyond the limits of the Trade-wind region, along the belt of high atmospheric pressure, there is in each hemisphere a belt of calms and variable winds, that on the north side being called the Calms of Cancer, that on the south side the Calms of Capricorn.

15. Out of each high pressure belt the winds blow towards the equator on the one side and towards the pole on the other. As the direction of the Trade-winds is deflected to the west by the influence of the earth's

ation, so the winds which emerge from the polar side of tropical calms acquire an easterly direction. In the thern hemisphere therefore they come from the south-st. In Britain, and the west of Europe, which lie siderably to the north of the Calms of Cancer, the alent winds are the familiar south-west winds. In countries it is common to find that the large s grow towards the west, and that the term "west-usually means the quarter where the best streets or ing-houses are situated. The reason is evidently to ght in the direction of the prevalent winds, for the nd south-west are the quarters which escape most town-smoke that is blown eastward.

Much interesting information may often be gathered ng the movements of the upper currents when still the atmosphere, as well as of other aërial currents, hing the clouds. In Britain, for instance, fine light ouds may be noticed at a great height, sometimes er heavy clouds lying below them. They may to move and change their shape, sometimes by these movements valuable prognostications ng weather.

ut the fact that [illegible] are upper currents in the ere is now [illegible] brought home to us still ikingly. [illegible] have been [illegible]dy referred untains [illegible] melted [illegible]n, and gas out, [illegible]hich the [illegible] sometimes [illegible] With such [illegible] enters a [illegible]ongly in one [illegible]ances, and [illegible] ever [illegible]ants [illegible]than [illegible]from

[illegible]

[illegible]

louds, it has been borne away by the overflow of air at he top of the hot ascending column, and after being arried for hundreds of miles by the upper currents, has t last descended to the surface again.

20. Clouds, ashes, and dust, therefore, sometimes give mportant evidence as to the direction in which the upper ërial currents are moving, and help to prove how regular nd constant is the circulation of the atmosphere.

21. Seasonal or Periodic Winds. — When the two harts of the world in Plates II. and III. are compared t may be seen that the larger masses of land in the northern hemisphere interfere a good deal with that regular distribution which, as shown by the southern hemisphere, a broad unbroken expanse of ocean favours. In January, for instance, the high and cold table-lands of Central Asia become the centre of a vast area over which the pressure of the air is high. Consequently from that elevated region the wind issues on all sides. In China and Japan it appears as a north-west wind. In Hindostan it comes from the north-east. In the Mediterranean it blows from the east and south-east. But in July matters are reversed, for then the centre of Asia, heated by the hot summer sun, becomes part of a vast region of low-pressure, which includes the north-eastern half of Africa and the east [illegible] ope. Into that enormous basin the air pours from [illegible] Along the coasts of [illegible] and Scandin[illegible] from th[illegible] From [illegible] round the [illegible] d Sea, [illegible] th-east, [illegible] from the [illegible] any place [illegible] land the [illegible]

word signifying any part or season of the year—but now generally applied to all winds which have a markedly seasonal character. Since the air is drawn in towards the heart of Asia in summer and comes out from that centre in winter, the direction of the monsoon at any place depends upon geographical position. In India the winter wind is the N.E. Monsoon, which corresponds to the N.E. Trades of the North Atlantic and North Pacific Oceans; the summer wind is the S.W. Monsoon, which is a complete reversal of the natural course of the Trade wind owing to the enormous in-draught caused by the low summer pressure over Asia. On the Chinese coast the winter wind is a N.W. monsoon, and the summer wind a S.E. monsoon. Similar but not quite so strongly contrasted monsoons occur in North America. In the Southern States, for instance, the winter wind comes from the north-east, the summer wind from the south-west.

23. Local Winds.—Many winds, often of a destructive character, occur in different countries or in different districts of the same country to which local names are given. When they come from tracts where the pressure is high and the temperature low to where the pressure is lower and the temperature higher, they are felt as cold blasts, whereby the humidity of the air in the low pressure area is condensed into torrents of rain. When around hot desert regions like those of Africa, Arabia, or the interior of Australia, a low atmospheric pressure occurs, its effect sometimes is to draw in towards it the hot air lying over these burning sands, which in the countries where it blows is extremely unhealthy. In Italy it is known as the *sirocco*—a hot moist wind which raises a haze in the air, and produces a sensation of extreme langour both in man and beast. In Spain, where it receives the name of the *solano*, it sometimes comes across the narrow part of the Mediterranean laden with fine hot dust from the vast

African deserts. In Africa and Arabia it appears as the dreaded *Simoom*—a hot suffocating wind which sometimes rushes across the desert with such violence as to raise clouds of sand, and sweep them in whirling masses for many miles. It thus heaps up vast mounds of sand under which caravans of travellers may be completely buried. One of the armies of Cambyses, 50,000 in number, is said to have been engulphed in the sand when on its way to attack the oasis and temple of Jupiter Ammon. Again on the coast of Guinea during December, January, and February, a hot wind, called the *Harmattan*, blows from the interior out to sea. The north-west provinces of India have likewise their hot-winds, which sometimes produce violent whirlwinds sweeping up the dust and carrying it in tall whirling columns into the upper air, whence it gradually finds its way to the earth again.

44. Storms.—But besides the winds and currents ...dy noticed, most of which blow continuously for ...s or months, there are sudden and violent commo... in the atmosphere often very disastrous in their ... These may be classed under the general name ... Let us see whether they can be accounted for ...neral princip... ...erial circulation which holds ...iodic winds.

...bursts upon a country with ...d rises rapidly into a gale and ...rush ... rate of often 70 or 80, some... s eve... ...nd 150 miles an hour. After ...s it sl... ...and may even die away ...as it ... ...gs up from a dif... or eve... ...ter, and possibly ...if it dr... ...and destructive... All pa... ...h ...the storm simul... ...usly ... in ... is usual for th... H

... Britain and the ... and Portugal catch the first ... travels eastward or north- ... Russia. The ... from place to place does ... thirty miles an ... the rapid and ... would have led any one to

... a storm has passed over Europe ... information as to the ... the countries traversed ... around its track. We find ... an area of very low ... in breadth, and ... much higher immediately ... The great law of atmospheric ... The air has ... surrounding regions of ... area of low pressure.

... that the ... between the low pressure ... of the high pressure ... of pressure lie to ... Suppose, for ... inches at ... inches at ... away: ... almost ... the air in ... spiral

vast up-streaming current, which overflows at the top and passes off into other regions.

28. Hence it is evident why, though the wind rushes so furiously, the whole body of the storm does not travel so fast in many cases as an ordinary passenger train. There are two motions in the storm, that of the whirling air as it is borne inward, and that of the whole rotating mass or storm. When the storm-ring bursts upon a place the wind may be blowing from the south-east. It dies down when the centre of the storm reaches the place, but rises again from the opposite quarter when the remaining side of the storm-ring advances, and continues until the whole whirling mass of air has gone by.

29. A good illustration of this vorticose movement of a storm is afforded by the little dust-whirlwinds often seen upon a dusty road in dry weather. The air in each of these, as shown by the movements of the dust, takes a rapid inflowing spiral course, drawing in air on all sides below and whirling it rapidly round and upward, till it expands at the top and flows over into the surrounding air.

Office of the Winds.—There are two kinds of work by the winds and currents of the atmosphere (1) ... of temperature; and (2) the distribution ... work ... referred to already, but ... in ... way here.

... a wi... from a warm or mild ... the te... of the places to which it ... vest a... est winds of Britain, for ... med b... d waters of the North ... p the a... much milder ... its latit... on the other ... d blow ... ion it lowers ... ature ... owing to the ... of ... inter and the

... winds are cold, and ... they make the ... and drier than ... A careful study of the charts ... will show this more clearly than a ... the areas of low ... direction the ... then a reference ... to us the tempera- ... from which the wind ... the wind in any particular ...

... the great agents by which the ... distributed over the globe. ... the condensed vapour would be ... from which it had been ... as by far the most of the ... would fall back again into ... get back the com- ... from rivers and ... the vapour along with ... pressure often ... is carried away from the ... the land. On the whole, ... place will depend ... winds come ... from a wide and ... laden with mois- ... chilled by passing ... they blow from the ... their heat or ... region whence

... travel from a ... cause they are

cooled below their dew-point and must let fall the surplus moisture. Winds are dry when they travel from a cold to a warm tract, because, instead of parting with their vapour, they are ready to take up more; they are dry too when they issue from a hot and dry region, and before they have an opportunity of crossing any sea and greedily drinking up vapour from its surface.

34. When a mass of high land stretches across the track of a warm moist wind, it forces the wind to flow up and over its ridges. The air is thereby expanded and cooled, and as a consequence deluges of rain descend. The most notable instance of this kind is that of the Khasi Hills already mentioned (Lesson X., Art. 31), which front the Bay of Bengal and interpose as a great steep buttress against the advance inland of the warm vapour-laden south-west monsoon. Driven up the slopes, the wind has to discharge its moisture in rain, of which, during the seven months when that monsoon blows, a depth of as much as 500 inches, or about 42 feet, falls to the ground. But, after passing over the hills, the wind, having lost so much of its moisture, is comparatively dry. Hence the rainfall rapidly diminishes northward. As the wind journeys in that direction, however, it is once more forced to [illegible] into the higher regions of the atmosphere [illegible] ain of the Himalaya. Its moisture [illegible] f it, as rain on the lower slopes, and [illegible] snow [illegible] gher ridges. And thus it descends [illegible] the [illegible] a cool dry wind into the wide plains [illegible]

[illegible] ies [illegible] India, therefore, the dry season [illegible] e changes of the monsoon [illegible] monsoon blows, whether [illegible]

[illegible] winds are irregular the rains [illegible] In the west of Europe, f

example, the wind shifts continually, but the prevalent winds are from the west and south-west, though during part of the year east winds become frequent. The westerly winds come from the warm Atlantic, laden with vapour, which they discharge plentifully on the western parts of Britain and the Continent, leaving the eastern districts comparatively dry. The easterly winds on the other hand come from the heart of Asia, and are so dry as often to wither up vegetation as much as a hard frost or even a scorching fire would do.

37. There is yet another kind of work performed by the winds, which, though of very limited and local character compared with their other services, deserves notice here. Storms by sweeping over the surface of the land sometimes produce great changes there, uprooting trees and

FIG. 12.—Sand-dunes—ridges of dry sand blown inland off the shore by the wind.

even prostrating large woods, destroying fields and houses and generally carrying ruin with them in their track. But even where the wind does not rush with such fury over the land it sometimes effects remarkable changes there when its prevalent direction is from the sea to the shore. On sandy beaches exposed to winds which usually blow

from the sea, the dried sand is often driven inland, where it forms mounds and ridges called sand-dunes, sometimes 60 or 100 feet high, fronting the beach for, it may be, many miles. A small streamlet, flowing behind these ridges may arrest their advance by carrying away the loose sand as fast as it creeps on. But where no such check exists, the sand may gradually extend inland, and completely bury the cultivated soil over whole farms or parishes.

38. Many examples of these effects are to be found along the coasts of the British Islands. Within the last few hundred years, thousands of acres of valuable land have been overwhelmed by the drifting of sand from the sea. Along the shores of the Moray Firth and of Aberdeenshire, for example, several parishes have been wholly or in great part buried. On the coasts of Norfolk and Suffolk, villages and thousands of acres of land have been covered with blown sand during the last two centuries, and on the Cornish coast similar inroads have taken place. The shores of the Bay of Biscay furnish still more striking instances of the power of the winds to alter the surface of a district. The dunes which are there heaped up by the westerly gales, march inland at a rate of 60 or 70 feet in a year. No barrier, natural or artificial, is able to withstand their progress.
woods, and villages are buried in succession. Nor
ll. The sand ridges interrupt the drainage from
rior, and the water collects among and in front of
ges. Ponds and lakes are formed, which, unable
an exit, are driven inland along with the sand bar-
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CHAPTER III.

THE SEA.

LESSON XII.—THE GREAT SEA-BASINS.

1. From the outer envelope of air which encloses the earth we now pass to the underlying envelope of water called the Sea. At the outset some obvious differences between these two coverings may be noticed. For example, while the atmosphere completely wraps round the whole planet, rising to a height of many miles above its general surface, the water envelope is pierced in many places by masses of the underlying solid part of the earth, which rise above it to form land. As the result of observations in all parts of the world it has been ascertained [illegible] the sea covers [illegible] quite three quarters, and the land [illegible] than [illegible]er, of the entire surface of the [illegible] the sea spreads over 144,712,000 [illegible]s, an[illegible] over 52,000,000 square miles, [illegible] area o[illegible]ce of the globe being computed [illegible] 12,000 [illegible]s.

Again, [illegible]thing about the upper surface of [illegible] atmosph[illegible]isely how far it lies [illegible]ve [illegible] forms a great plain, [illegible] is sharply defined. [illegible] sea [illegible]ng a plain, we know

39. It is not always along the sea-margin tl effects of the action of wind are to be traced. interior of many countries there are wide tracts (sand or Deserts (Art. 23), over which the wind r sand into ridges, as it does along the shore. ! instance, are the great desert of Sahara and muc interior of Arabia.

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2. Again, we know nothing about the upper surface of the atmosphere, and cannot say precisely how far it lies above us, but the surface of the sea forms a great plain, and the line between it and the air is sharply defined. Though we speak of the sea as forming a plain, we know

this plain to be really curved, and that from its wide extent and its freedom from inequalities, it shows the curvature of the earth's surface better than can be seen on land. (Lesson I. 2.) The amount of the curvature is about eight inches in a statute mile; that is, an object eight inches high above the sea-level sinks out of sight when looked at from the same level at a distance of more than a mile. The line of meeting between the sky and the surface of the earth is termed the horizon. Its distance from us evidently depends upon the elevation at which we may happen to stand. Thus, at the sea-shore with our eyes exactly six feet above the sea-level our horizon out to sea is three miles off. If we ascend so that our eyes are about ten feet and a half above the sea-level, our horizon is extended to four miles. If we climb to some adjoining height, say to a lighthouse top, about ninety-six feet above the sea, our horizon is increased to a distance of twelve miles.[1]

3. Another evident contrast between the air and the sea lies in the fact that while every inhabitant of the earth is familiar with the one, only a comparatively small part of mankind has ever seen the other. Even in a small and populous island like Britain, a large proportion of the inland population has never been within sight of the sea. On the continents the proportion must be much greater, for, except the people dwelling along the sea-margin, the great mass of the inhabitants, having little or no communication with the coasts, have no acquaintance with any larger sheet of water than their own native river or lake.

4. It is hardly possible that any one who has not seen the sea can realize what it is from descriptions in books.

[1] In estimating the extent of the visible horizon, however, when the distance exceeds half a mile, we need to take into account the effect of atmospheric refraction which tends to make distant objects seem higher than they are. The allowance to be made for this effect varies from day to day: it *commonly* requires a deduction of about one-seventh from the apparent *height of* an object.

Let us suppose, however, that some intelligent dweller in
he inland regions were taken for the first time to the sea-
oast, and after recovering from his first impression of
onder and admiration, were to begin to look attentively
those features which would be most likely to attract
attention. He would observe that the solid ground,
h which he had been familiar all his life, gives place to
eemingly boundless plain of water, at first sight level and
tionless, but soon found to be in a state of perpetual
est, and answering to all the movements of the air
ve, heaving or rippling when the air is gently stirred,
rising into waves and foam-crested breakers along
shore when the wind blows strongly. Should he taste
of this blue sparkling water he would find it salt
undrinkable, even though clearer perhaps than his
river at home. Gathering the shells and other
ns of the living things of the sea from the sands of
ore, he would find every one of them different from
ng he had ever found on the land or in the fresh-
If he watched by the shore from day to day, he would
at *twice* every day the water advances slowly and
retreats, and that this regular movement takes
ether the water be smooth or rough. Were he
upon that seemingly boundless plain of water,
at behind him gradually sinking as
at last its highest point had
long level line of meeting be-
then sweep around him on every
ight and no other vessel perhaps
overhead and the heav-
ould learn better than
tness and solitude of
eck, or even from the
aratively small patch
The horizon or sky-

line, which he thinks so immeasurably distant, is only a few miles off. When standing on the sea-level he cannot see an object on the same level as high as himself at a greater distance than about six miles in any direction. And he might sail for weeks together, passing over thousands of miles, with all the time the same limited horizon and the same monotony of sea and sky.

5. The traveller who finds himself for the first time on the open sea is not only impressed by the vastness of its surface, but by a vague notion of its profound depth. He has read of the "unfathomable abysses of ocean," and naturally feels some awe at the thought that they are actually lying beneath him. In recent years, however, Expeditions have been fitted out to measure the depth of the sea in all parts of the globe, and the result has been to show that even the deepest of the so-called abysses probably does not much exceed five miles, while the average depth of the sea may be taken at about half that amount.

6. Had the earth been a perfectly smooth globe like a ball of polished steel, we may suppose that the sea would have completely covered its surface. There would then have been an outer shell of air and an inner shell of water, within which the solid planet itself would have lain. The average depth of such an universal sheet of water as may be inferred from what has been made known by numerous soundings in all parts of the present sea, would have been rather more than a mile. Probably the water envelope never completely wrapped the globe round in this way: at all events, owing to the irregular projections and depressions of the solid part of the earth, the sea is now broken up into separate basins or oceans by intervening masses of land.

7. Looking at a map of the world we may be disposed to ask whether any reason can be given for the shape which the great ocean-basins have taken. We may *wonder* whether the sea, by the force of its own waves

d currents, could have hollowed out the great depres-
ons in which it now lies. But if we try to follow out
is subject we soon find that the sea could have had very
ttle to do with the formation of its basins. It is, as we
hall learn in Lesson XVIII., only the upper parts of the
ea which eat away the solid part of the earth ; the water in
he deep abysses does not even stir the fine mud, which,
ike dust in a deserted room, slowly settles down upon
the bottom. Where the waves wear down the land, the
materials which they remove are not destroyed, but are
carried away into some still part of the sea, where they
accumulate on the sea-floor. So that even if we could
suppose it possible that the sea might have scooped its
basins out of the solid surface of the globe, it could only
remove the *débris* from one part of its bed to another,
and, in short, fill up its hollows after it had formed them.

8. It is not the action of the sea, then, but the sinking
and uprising of the solid surface of the globe, which has
determined the shape and size of the great sea-basins.
Consider what was said in Lesson III. about the probable
history of the earth. If our planet has slowly cooled from
a condition of intense heat, it must have gradually con-
tract ... ulk. We may compare it to an apple which
is ... while, until it begins to dry up, and conse-
... ak. The apple does not diminish equally
... me parts of the skin sink down, others get
... wrinkles and foldings, so that in the end
... th surface becomes shrivelled and uneven.
... contraction has likewise been
... ave sunk down, others which
... me more and more wrinkled,
... t. The depressed parts have
... e oceans. Those portions of
... rise above the sea-level form

9. Until a comparatively few years ago, the abysses of the sea were as unknown as the interior of the earth. Their depth was only guessed at, for the few attempts to measure it had led to great exaggeration. The nature of their floor was equally a matter of conjecture. It was supposed, indeed, that the water at these profound depths lay dead and motionless, that no living thing could possibly exist at the bottom, and that no change went on there save the slow accumulation of fine mud, carried by ocean currents from far-distant land.

10. But much of this uncertainty has now been dispelled. Expeditions to measure the depth and explore the bottom of the sea have been sent to all parts of the world, and have collected such a mass of information that we now know more about the depths of the ocean than about some parts of the continents. Three instruments have been used in these researches : the Sounding-line, the Dredge, and the Thermometer.

11. The Sounding-line consists essentially of a rope or cord with a weight at the end, so arranged that when dropped from the side of a vessel to the sea-bottom the amount of line which runs out from the reel is accurately registered and at once indicates the depth. The weight may have its bottom covered with lard, or other soft material, which, when it strikes against the bottom, will bring up some of the mud, sand, gravel, or other indication of the nature of the ground below. The Dredge consists of an iron frame with a strong net or bag attached to it ; the object of this instrument being to bring up a more considerable quantity of the materials which form the sea-floor, as well as any of the living or dead plants and animals to be found there. The Thermometer has been used to such good purpose that the temperature of the vast Atlantic and Pacific Oceans has

een determined at many points from the surface down to ne deepest parts of the bottom.

12. At present, the tract of sea which has been most horoughly explored is that of the Atlantic Ocean. As shown upon a map of the globe, this Ocean runs as a long and winding belt of water between the New World and the Old. Towards the north it is rather closed in by the convergence of the American and European continents with the islands between them, though a free, open communication is maintained between the Atlantic and the Arctic Ocean. Southward from the equator it gradually widens out and merges eastward into the wide Indian Ocean. Hence, though narrow in comparison with the vast basin of the Pacific, the Atlantic is really longer than that ocean, for there is no such close approach of the coasts of Europe and America as there is between those of America and Asia, which bound the Pacific to the north, and divide it from the cold Polar waters beyond Behring's Strait. It has been estimated that the ... of the Atlantic Ocean amounts to ... the whole area ... miles, which is nearly a fifth part of ...,165,000 square ... the entire surface of the globe.

13. Stretching th... from pole to pole, it crosses all the vario... ...f ... temperature which girdle the globe. ...cent ... the shores of equatorial America ...d Af... these, it reaches the temperate climate... America and Europe. At either end it ente... ...ns of the Pole.

14. ... ...rangement of the continents ...whic... ...ast, the Atlantic receives ... fa... any other ocean. The ... length of America all ... and therefore fall into the ...ssissippi, Orinoco, Ama... ...e and Africa, if we include

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finds its
as the
and Congo.
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have a depth of from 2,000 to 3,000 fathoms, or from about 2 to 3½ miles. It would seem, therefore, that these submarine tracts form a vast plain, rising in some parts into ridges, such as that of which the Azores form the highest elevation.

18. To the west of the British Isles for 230 miles the slope of the ocean-bottom is very gentle, being only six feet in the mile. But beyond that distance the ground descends so rapidly, that in the next 20 miles there is a fall of 9,000 feet, down to the level of the great submarine plain, which stretches for hundreds of miles to the west, with little variety of surface.

19. The Pacific Ocean has not been so diligently examined as the Atlantic. But some recent soundings, taken during the great cruise of the ship *Challenger*, show a still greater depth than those in the latter ocean. One observation, taken in the North Pacific between Japan and Admiralty Island, gave the enormous depth of 4,475 fathoms, or rather more than five miles. Another gave 3,950 fathoms, or about 4½ miles. These are the deepest ocean-abysses which have been accurately measured.

20. But these are exceptional depths. The greater part of the North Pacific, like the North Atlantic Ocean, seems to average from 2,000 to 3,000 fathoms. The vast Pacific basin is traversed by many ridges, as may be seen on the map, from the chains of islands which dot its surface. One vast ridge rises along the northern margin of the basin, and stretches from the American coast through the Aleutian Islands to Japan, thence by the Philippine Islands, New Guinea, and the New Hebrides to New Zealand. In mid-ocean the tops of other vast ridges are indicated by the scattered archipelagoes, such as those of the Caroline, Marshall, Sandwich, Marquesas, and Society Islands. (See Lesson XIX.)

21. The map of the world shows that although the

great water envelope of our planet may, for the sake of convenience, be parcelled out into separate oceans, these are all united into one vast continuous sheet of water. Here and there, however, owing to the way in which the land has been ridged up, portions of the water have been almost separated from the main mass. These are called *mediterranean*, the best example being that which has long been known as the Mediterranean Sea. The Black and Baltic Seas in Europe, Hudson's Bay and the Gulf of Mexico in North America, the Red Sea, Persian Gulf, and Seas of Japan and Okhotsk in Asia, are other illustrations. But sometimes the uprise of the land has taken place in such a way as to cut off completely some outlying parts of the oceans. These are termed *inland seas*. The Caspian Sea and Sea of Aral are the most important instances of this result. The former sea covers a larger space than the British Isles. Its surface is about 85 feet below sea-level, and its greatest depth amounts to nearly 3,000 feet. Its waters are inhabited by seals and other marine animals, while in the tracts of land which now inclose the Caspian and Sea of Aral and separate them from the Black Sea on the one hand, and the Arctic Ocean on the other, beds of dead sea-shells are found. Reference will be made in Lesson XXIII. to the proofs that the land along the coast of Siberia has in comparatively recent times been raised out of the sea. The extent of the upheaval is generally indicated on the map in Plate IX. Before this uprise the Arctic Ocean seems to have extended in a long arm between Europe and Asia as far as the hill-range which is now cut through by the narrow channel of the Bosphorus, but not to have communicated with the present Mediterranean Sea. By the rise of the land towards the north all that part of this vast inlet lying to the south of the parallel of 50° or 52° N. was cut off from the main

ın. The present abundant salt lakes and marshes, rell as the two large basins of the Caspian and Aral, t be looked upon as the mere shrunk remnants of this Mediterranean sea. In some yet unexplained way the rvening ridge between the Black and Mediterranean s has been trenched, so that the former sea no longer ıs part of the Caspian basin, but sends its surplus ers through the Bosphorus and Sea of Marmora into Mediterranean. There seems also to be less rain now ı formerly in the region of the Caspian and Aral, so t these sheets of water are still further shrinking.

LESSON XIII.—THE SALTNESS OF THE SEA.

The aqueous vapour of the atmosphere is in great rived from the evaporation of the surface of the d as the sea does not get sensibly lower in level tanding the enormous volume of moisture which lly driven off from it into the air, it must receive n from the rivers which descend to its shores, e rain which falls upon its surface, as much it ··plies. T 'ius a ceaseless coming ·· ·ter sea, the air, and the

wate s examined in different .ssag great varieties. Rain is .sed fr distillation, and is nearly rtheles ·ste, and when ı Lesson VI., it has taken rivers always s after evapor- ess. · But sea-

water is always strongly salt to the taste, and this is true of the sea in all quarters of the globe.

3. Another distinction between the water of the air or of springs and rivers, and that of the sea, is shown in their different weights. A bottle filled with sea-water weighs more than when filled with fresh-water. Perfectly pure water being taken as the unit, sea-water has an average relative weight, or specific gravity, of about 1·026; in other words, if a certain quantity of perfectly pure water weighs 1,000, the same quantity of sea-water will weigh 1,026. The water of the different oceans varies slightly in density. That of the Atlantic, for example, varies more and is generally heavier than that of the Pacific. In the path of the trade-winds in the North Atlantic, where evaporation must be comparatively rapid, some of the heaviest and of course saltest sea-water occurs, its specific gravity being 1·02781. In the Antarctic Ocean, on the other hand, among the broken ice, the specific gravity sinks to 1·02418.[1]

A striking proof of the greater lightness of fresh-water may sometimes be seen after heavy rain has fallen in still weather upon the sea. The rain floats on the surface of the sea, and so does the water brought down by streams from the land. Fresh drinkable water may then be taken from the surface of the salt-water which lies below, until unless more quickly mingled by wind and waves, the fresh-water slowly diffuses itself downward.

4. What is it that makes the sea-water heavy and salt? To answer this question for yourselves, get, if you can a small quantity of sea-water. Evaporate it till only a little of it remains, which tastes extremely salt and bitter. Stirring this remaining liquid, so as to mix it completely, put a drop or so upon a piece of thin glass and place the glass under a microscope. Now watch what takes place.

[1] Buchanan, *Proc. Royal Society* (1876), vol. xxiv.

one of the simplest and most beautiful experiments can make. The drop continues to pass off into ıur, but the substances which gave the water its salt bitter taste cannot do so. They remain behind, and ıe water leaves them you see them one after another ›ting into the most perfectly symmetrical crystals. ıderfully interesting is it to watch how the little par- :s rush to each other, and unite to form those exactly

—What is seen when a drop of concentrated sea-water is evaporated under a microscope.

ioned outlines. First you observe some oblong,
ns (gypsum, … phate of lime), which pro-
ıppear b… ou took the drop out of
salt-… n, as the drop rapidly
wd of … res marshal themselves
edges, … of the water passes off,
icle an … comes fixed and motion-
ave dri… e water, and what you see
s are t… ich … the sea-water its
tic, … t. live far away
sea you … part … xperiment by
dr… of … hicl … common salt

has been put as it will dissolve, and placing it under the microscope. The square crystals will be seen growing round each other with great vigour and in perfect symmetry.

5. While the different forms of crystals indicate the different saline materials present in the sea-water, each substance which crystallises keeping its own form of crystals, the relative abundance of each form shows in a general way the proportions in which the substances occur in the water. We see, for example, that by much the most abundant are the square or cubical crystals. These belong to what we call common salt, or chloride of sodium. Moreover, they come last in the order of appearance of the crystals, whence it is clear that they can remain longer dissolved in the water than the other substances. They are therefore said to be more soluble. Now while the dry film left by the drop is still below the microscope, breathe gently on it, and watch what takes place. The moisture of your breath dissolves the crystals one by one, until, if you have supplied moisture enough, they wholly disappear in the little drop of water which now replaces them. The cubical crystals of salt vanish first. Should there be much vapour in the air, you may not be able to keep the crystals from attracting it and dissolving, unless you heat the glass before a fire.

6. When sea-water is analysed it is found to contain about three-and-a-half parts by weight of these various salts in every hundred parts of water. As our evaporated drop indicated, common salt forms by much the largest proportion, at least three-fourths, of the whole amount of salts. The other saline substances are called chlorides of magnesium and potassium, sulphates of lime (gypsum) and magnesia (Epsom salts), and some others in still smaller quantity. The proportions do not greatly differ throughout the whole extent of the ocean.

7. The next question that arises is, Whence does the sea get its salt? This is not quite so easily answered as the previous one. We cannot tell what the earliest condition of the sea may have been. Probably its waters have always been salt ever since they condensed out of the original atmosphere of gas and vapour, and carried down the saline vapours which were no doubt at first diffused abundantly through that atmosphere. But even if the sea had been quite fresh at the beginning, it would have been perceptibly salt now. In Lesson XXVII. you will find an account of the way in which the fresh-waters which flow off the land, all, without exception, carry saline substances into the sea. As this process goes on without ceasing, and in every quarter of the globe where land exists, no one can fail to understand how vast must be the yearly tribute of this kind received by the sea from the land. Probably, if our methods of analysis were delicate enough, it would be possible to detect in sea-water traces of every substance which is dissolved in the waters of the springs, rivers, and lakes of the land. Some ingredients, for example, which are present in too minute proportion to be detected by chemical analysis of a small quantity of sea-water, are extracted by marine plants and animals, and found in their tissues or skeletons. The copper bottom of a ship which has been sailing for [illegible] ers out some of the dissolved [illegible] or othe[illegible] are diffused through the [illegible] the [illegible] bstances are likewise found [illegible] crust [illegible] side the boilers of ocean-[illegible] ers wh[illegible] used.

Amon[illegible] present in sea-water in such [illegible] notice, there are [illegible] their names in [illegible] The former of [illegible] miliar forms of [illegible] mainly built up.

When embodied by these sea-creatures as part of their skeletons, it becomes the white chalk-like substance which we recognise as the material composing the common shells of the sea-shore. Silica is secreted by lowly forms of plant and animal life in the sea. The hard compact stone called flint is a common form of ancient sea-grown silica.

9. Sea-water likewise contains **air**. That this must be the case is evident from what takes place in windy weather at sea. The surface of the water is tossed up into waves, and these are blown into spray. The sea becomes a sheet of white foam, which is a mixture of air and water. Some of the air remains dissolved in the water after the waves have disappeared, and is slowly diffused even to the depths of the ocean. The quantity of air present in sea-water varies from time to time; sometimes it has been found to amount to no more than one-hundredth of the volume of water, at other times to as much as one-twentieth.

10. Does this seem a small proportion? At all events we cannot but look upon it with interest, for it is this included air which enables the animals of the ocean to breathe. They inhale it, and exhale carbonic acid. Hence that gas, besides the proportion of it in the dissolved air, is likewise present in sea-water. In the higher parts, which come under the influence of the waves, the carbonic acid is partly removed, and fresh supplies of air are furnished in its place.

11. There is still one other substance in sea-water deserving of notice here. It is called **organic matter**, or **protoplasm**, the material which serves the simpler forms of marine creatures as food. It seems to be derived from the substance of plants and animals both in the sea and carried by rivers from the land.

12. It appears, then, that the sea is salt, partly probably from the vapours of the original atmosphere from which

condensed, partly because many different salts are
ntinually carried into it by brooks and rivers; that it
ntains in solution more or less of all terrestrial substances
nich water will keep dissolved; that it is aërated by
ie waves, the air being diffused through its mass, and
rving for the respiration of marine animals; and that
om the dead bodies of animals and the remains of
lants, both on land and sea, the fundamental substance
r protoplasm of which plant and animal forms are built
s diffused through the whole mass of the ocean.

LESSON XIV.—THE DEPTHS OF THE SEA.

1. From what has been said in Lesson XII. it is plain that the bottom of the sea must be uneven and undulating, like many parts of the surface of the land; stretching out in some parts into vast plains, rising here and there into broad and long ridges, shooting up into vast precipitous slopes, like that of the Atlantic floor to the west of Britain, sinking into deep hollows, which descend far below its general level, as lake-bottoms do below the general level of the land, and traversed by mountain ranges, of which the oceanic islands are only the unsubmerged peaks. But what is the nature of the surface of the sea-floor? Is it solid rock, or soft mud, or barren sand,—or are the submarine plains covered with an oceanic vegetation, as the plains of the land are with grass and herbage?

2. S[illegible]ing by the margin of the sea we observe that
[illegible]ks upon sand, gravel, mud, or strewn frag-
hells, and that these materials pass down
shore is rocky, pools of the salt-water may
hich some idea may be formed of the
om of at least the shallower parts of the

sea. Each of these pools forms as it were a miniature sea. Its sides are hung with tufts of delicate sea-weeds and bright with clusters of sea-anemones, while many a limpet and periwinkle stands fixed to the stone, or creeps cautiously over its surface. The bottom of the water abounds in shady groves of sea-weed, through which many tiny forms of marine creatures dart or crawl. As we look into one pool after another we find them all to be more or less full of plant and animal life.

3. Turning from these shore pools to the edge of the sea itself when the tide is low, we mark that the ledges of rock support a thick growth of coarse dark green or brown tangles and sea-wrack, among which, if the water is still enough, tiny crabs, sea-urchins, jelly-fish, and other bright-coloured marine animals may be seen. If the water is examined from a boat, this forest-belt of large dark sea-weed is found not to extend to a greater depth than a few fathoms. Beyond it the bottom, whether rocky, sandy, or muddy, can be seen through the clear water, or may be examined by means of the dredge. Delicate scarlet sea-weeds with corallines and deeper-water shells inhabit these tracts. The sea-weed belt which fringes the land has an average breadth of about a mile. Beyond it, as we gradually get into deeper water, the common plants and animals of the shore are found one by one to disappear, and other kinds to take their place. The dredge may be dragged along some parts of the sea-floor and bring up only sand or mud, while at a short distance off it may come up full of many and varied forms of marine life, thus showing that there must be bare tracts of sand, mud, or stone on the sea-floor, and other patches where plants and animals are crowded together.

4. Down to a depth of about fifty fathoms the waters of the ocean round the margin of the land abound in plants and animals. This upper and marginal belt

: some of its deeper cavities have the icy temperature 4°.

In the North Pacific Ocean a general bottom temre below 35° Fahr. has been observed. Sometimes ly of water of this low temperature exceeds 2,000 ; in depth. In the South Pacific Ocean, beyond tway, Australia, the bottom temperature sinks to ile further south (Lat. 53° 55′ S.), the body of below 35° comes within less than 100 fathoms surface. Below a depth of 1,000 fathoms the s cold as ice (32°) down to the bottom, where meter marked 31° at a depth of 1,950 fathoms. low temperature of all but the upper parts of the at as the deep water could not be cold unless it old latitudes, there must be a continual transater from the cold Polar tracts towards the e heavy cold water sinks down, and creeps upper warmer layers. These, again, move oles to supply its place. When the cold water uatorial regions, it rises towards the surface, radually warmed, it moves away again as owards the poles. Hence these soundings the various temperatures of the sea, but evidence of vast slow movements, by of the sea are constantly mingled and tion.

mperature soundings have sometimes other way proof of the slow circulation sea. In the North Atlantic, between Faroe Islands, below a uniform surface —53° Fahr., two parallel belts of water lying side by side and having nearly one of these the bottom temperature ·7°, in the other 29·6°. Two very s were thus ascertained to lie close

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Lesson XVIII.
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noticed. As they drift onwards into warmer latitudes they melt away both under water and above. Cascades of water tumble down their thawing slopes and fall into the waves below. It often happens that as the melting goes on under water, the centre of gravity of an iceberg is altered, so that the mass shifts its position, or, becoming top-heavy, turns completely over.

, at Sea.

uch are icebergs which in summer the nav across the Atlantic between oundlan a serious source ountered at any ruck against one They chill the air of to dense fogs.

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t the temperature soundings have sometimes out in another way proof of the slow circulation ater of the sea. In the North Atlantic, between d and the Faroe Islands, below a uniform surface ature of 50°—53° Fahr., two parallel belts of water n observed lying side by side and having nearly depth. In one of these the bottom temperature o be 42·7°, in the other 29·6°. Two very imates were thus ascertained to lie close

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memorable Arctic voyage of the Austrian vessel *Tegetthoff*, which, after almost incredible endurance, was even-

FIG. 17.—Scene among the disrupted ice of the frozen Arctic Sea.

...ageous crew, who, t...

boats or sledges drawn by dogs, pushed across the frozen sea and reached Novaya Zemlya.[1]

7. In consequence of the breaking up of the vast sheet of ice, openings are formed in which the unfrozen water can be seen, until it is fast bound in ice by the cold. These water-channels or lanes, between the separated fragments, are the passages, by which vessels make their way through the ice-pack. But as the great sheets are carried against each other in the general movement, it sometimes happens that a ship is caught between them, and pushed up on the floe, or crushed so effectually that it goes to the bottom as soon as the fragments of ice separate again.

8. Except where piled in heaps by pressure, which breaks up its surface as well as its outer edges, floe-ice occurs in level sheets, the surface of which rises but little above the level of the sea. It never rivals the height and grandeur of true icebergs, though it covers a much wider space of sea. Nor does it travel so far from the regions of its birth. When the ice-field breaks up in summer the portions next the land may remain there, and of these indeed some parts may continue unmelted for generations. But other parts further from shore, and sometimes many hundreds of square miles in extent, are loosened and carried away by the sea-currents which drift from the pole. Vessels frozen into the ice-field have in this way been carried many hundreds of miles, until disengaged by the disruption and thawing of the ice. Some of the icebergs from Greenland, however, travel much further south, and may be met with now and then even as far south as lat. 37°, that is, about the same parallel as Richmond in Virginia, and Cape St. Vincent in the south of Spain.

[1] For a graphic account of this and other Arctic voyages, see *New Lands Within the Arctic Circle*, by Julius Payer.

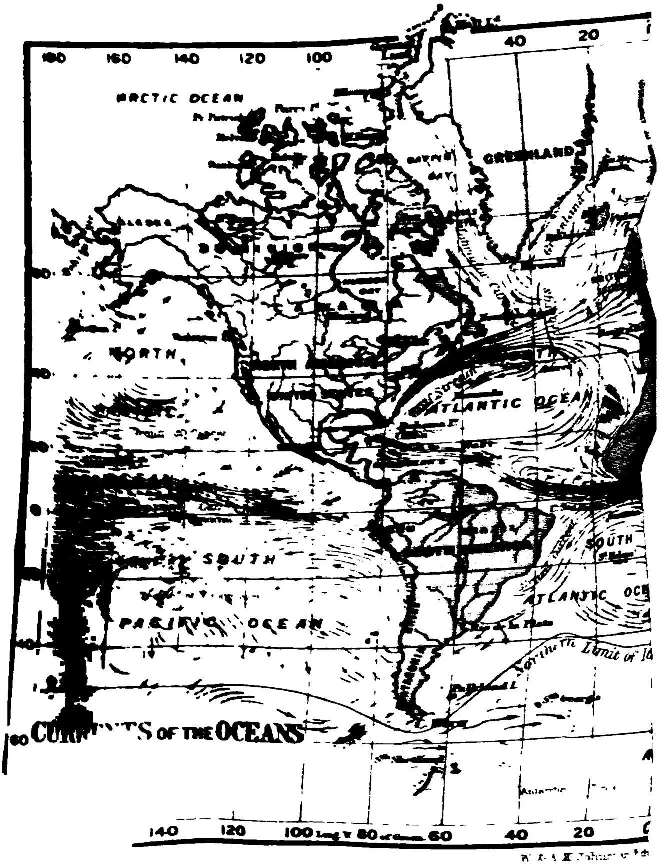
9. When the sea freezes along the margin of the land, as it does in a remarkable way in North Greenland, it forms a cake of ice which, rising with the tide, is frozen to the shore. By degrees a shelf of ice, called the **Ice-foot,** rising from twenty to thirty feet above the general level of the floe, and having a width of 120 feet or more, forms along the coast and clings to it all winter. Immense quantities of earth and stones, dislodged from the coast

18 —The Ice-foot of Greenland.

cliffs ... frost of the Arctic winter, fall upon the ice-fo...s surface becomes in some places a field ... completely covers and conceals the ice ...en the summer storms come, this shore- ...broken up, and large pieces of it, la- ... the cliffs, are floated away out

there to join the fleets of bergs and broken sheets of floe-ice. Some portions are driven ashore again, others are caught and frozen fast into the floe-ice of next winter, while others succeed in escaping into the more open sea, where they gradually melt and tumble their load of earth and stones on the sea-bottom.

10. Floe-ice and the ice-foot are formed by the freezing of the surface of the sea. There is yet ancther way in which some of the ice of the sea takes its origin, viz., by the freezing of the water lying on the sea-bottom. This is known as **Ground-ice.** It is probably formed only in inclosed and shallow seas and inlets, and is of little consequence compared with the thick and wide sheets of floe-ice. It is well known in the Baltic Sea. In still weather, before the surface of that sea is frozen, little thin cakes of ice may be observed floating about, sometimes with portions of sand or scattered pebbles imbedded in them. These are formed on the bottom, from which they break away and rise to the surface. They form a source of some danger, at least to small boats, for they sometimes appear suddenly in such numbers as to cover the sea, the surface of which is then apt to freeze too, so that the boats are in danger of being nipped between the detached ice-rafts, or of being beset and frozen into the united cake of ice. Sometimes large blocks of rock as well as masses of seaweed are borne away from the sea-floor and carried to the surface by the ascending sheets of ground-ice. In the rivers of cold countries, as for instance, in the St. Lawrence, similar ground-ice is formed in winter, sometimes round iron chains or anchors, which, if the inclosing ice is thick enough, may actually be lifted by it.



ARCTIC OCEAN
GREENLAND
NORTH
ATLANTIC OCEAN
SOUTH
PACIFIC OCEAN
SOUTH
ATLANTIC OCE
Northern Limit of Ic
CURR S OF THE OCEANS
180
160
140
120
100
40
20
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100
80
60
40
20


Franz Josef Land
40
80
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120
140
160
180
ARCTIC OCEAN
Spitzbergen
NOVAIA ZEMLIA
Liakov Is
New Siberia
Arctic Circle
SIBERIA
RUSSIAN EMPIRE
RUSSIA
L. Baikal
OKHOTSK SEA
Kamtchatka
ASIA
CHINESE EMPIRE
TURKESTAN
NORTH
Desert of Gobi
JAPAN SEA
60
40
PERSIA
TIBET
PACIFIC
Japan Current
CHINA
Tropic of Cancer
ARABIA
INDIA
B. OF BENGAL
20
ARABIAN SEA
CHINA SEA
Philippine Is
OCEAN
Ceylon
Borneo
Equatorial Current
Equator
Sumatra
0
Solomon Is
INDIAN OCEAN
Java
SOUTH
Madagascar
Fiji Is
Tropic of Capricorn
AUSTRALIA
PACIFIC
NEW ZEALAND
St Paul
Tasmania
Crozet Is
Kerguelen Land
OCEAN
Macquarie I.
OCEAN
Adelie Ld
Enderby Ld
South Victoria Land
60 Long. E. 80 of Green. 100
120
140
160
180

LESSON XVII.—THE MOVEMENTS OF THE SEA.

The restlessness of its water is one of the features e sea which first impress the onlooker. Even in a calm when not a leaf appears to be stirring on the earth, he clouds seem perfectly motionless in the sky, the ay be seen heaving, or curling into faint ripples, or ' in broad undulations which break into foam when each the shore. On the other hand, in stormy r the unrest of the air is fully equalled by the ious uproar of the sea, when clouds of driving l salt sea-spray are swept along by the tempest ilmost seems as if sea and sky were commingled. : do not at first perceive that the movements of re not all by any means so fitful and capricious ppear to be, but that, on the contrary, they are by easily understood laws, and can be foretold ed be, provided against. Nor do we at once what different causes these movements are

is suppose that, placing ourselves in some position for observing the motions of the sea, y register the facts which come under our e margin of any of the great oceans would or the purpose. Such a coast-line as that of reland, for example, forms an excellent field n, allowing opportunities of watching some characteristic movements of the water of a asin.

st point we remark is the obvious close etween the motion of the air and that of a rule, when the air is still the water is on some days we should find that e good deal of agitation might be c

[illegible] heavily [illegible] sea [illegible] new [illegible] and [illegible] answering [illegible] the same [illegible] and [illegible] so [illegible] the [illegible]

[illegible] of the [illegible] same of [illegible] that of [illegible] the whole [illegible] movement [illegible] cannot [illegible] we find [illegible] distance and [illegible]

face of the sea may be observed slowly to sink during
ut six hours, and then for a corresponding interval
ly to rise again. On a flat or gently shelving shore
vertical movement manifests itself in another way.
fall of the water lays bare wide stretches of rocks,
or mud. During the retreat of the sea we notice
each ripple or wave does not come quite so far as
which preceded it. Step by step the waves seem to
iwn back, until in some large bays many square
f flat ground are laid bare, across which we might
During the advance of the water, on the other
ach succeeding wave comes a little further up the
ian its predecessor, until all the uncovered flats
: more under the sea, and boats can sail over
hich two or three hours before we may have
on foot. This rise and fall of the sea is known
les.

ttle observation enables us to make quite sure
regular movements have no connection with
ie air. Even when a strong gale is blowing
and, and driving the surface of the sea into
ves, it does not arrest the advance or retreat
The waves continue to creep up or down the
n the face of the wind.

we cannot but remark the wonderful regu-
movements. Each advance of the water
ier more than six hours, and each retreat
ame interval, so that the time of high or low
: foretold with accuracy. From an early
an history, and long before the real cause of
inderstood, it was observed that there is a
on between them and the state of the moon.
f the observations which we have supposed
ike, we find that the time of high wate
th the passing of the moon across

meridian, and that the highest and lowest tides occur at the time of new and full moon.

9. Putting now the sum of these observations together, we have ascertained the existence of three distinct kinds of movement in the water of the sea. First, wind-waves; second, surface-drifts or currents; and third, tides. From what was said in Lesson XV. it is clear that a fourth form of motion must be added to these, viz. that general creep or movement of the cold polar water along the bed of the sea towards the equator, and the flow of the upper waters towards the poles. We must consider each of these movements a little further.

10. (i.) **Wind-waves.** These, like the ripples we send along the surface of a trough of water by blowing briskly at one end, are due to the pressure of the wind. Viewed from the top of a high cliff, or from the mast of a ship at sea, they are often seen to succeed each other in long parallel lines, travelling regularly and rapidly across the surface of the sea. Though the waves move forward, the water itself in the open deep sea shares but slowly in this movement. It rises and falls with a slight oscillation as each wave passes, though, if the wind continues to blow for a time, the surface water is gradually pushed onward. A field of corn or tall grass may often be observed to be thrown into waves as a smart breeze sweeps over it, yet each stalk and blade retains its place, and merely bends up and down and to and fro with a kind of motion like that of the particles of water in a wave.

11. When the sea has been thrown into violent agitation by a storm, the waves do not at once subside when the storm is over, nor do they remain confined to that region only through which the storm has passed. So sensitive is the great body of oceanic water that the waves are propagated far beyond the area of the storm in vast undulations, or *ground-swell*, as this heaving is called.

the deep water of an open ocean the only trace of this)vement is seen in the broad undulations which, like a ;at pulse, keep the surface regularly rising and falling. ship sailing over this surface alternately mounts on the , of a swell and sinks into. the trough between two of m. But as the sea gets shallower towards land, the up- l-down movement passes into a true onward rush of water. The upper part of the undulation travelling er than the lower parts, which are impeded by the ion of the bottom, begins to assume the aspect of a e, curling over as it advances like a huge wall of green r, to burst into foam against the land.

. The motions of waves and ground-swell must be sible in the deeper parts of the sea. In reference to reat body of the sea, they are merely surface agita- probably seldom extending sensibly more than a few 'ed feet downwards. So that when a hurricance is g the surface of an ocean into the most violent com- ı, we must think of the deep abysses below as dark, and calm. And this is a matter of some importance ve consider the various offices of the sea, as will be ı the following Lesson.

Since the longer the space of deep sea over which ıd has to blow, the larger are the waves, we may :o meet with the grandest waves in the great oceans. ıccounts of storms at sea it is common to meet :h expressions as that "the waves were mountains The size of waves is apt, however, to be much ıted. Thus, a series of measurements, taken during : across the North Atlantic, gave forty-three feet .treme height of the waves in stormy weather. In ıw British seas, which are in a great measure r from the Atlantic, the largest waves are less the maximum size which they attain in that

14. No one can watch one of these huge waves as it nears the land without being impressed by the great force with which it beats upon the coast. The scene represented in the frontispiece of this volume may give some idea of the grandeur of a stormy sea. Each long undulation which rolls in from the outer sea mounts higher as it approaches the shore. At every step it becomes a more and more marked ridge of water, which begins to curl into a green-crested wave with a steep concave front towards the land. By degrees the upper advancing crest topples over, and the immense mass of water plunges with all its weight upon the rocks or sand of the coast-line. When the broken water has spent itself in rushing up the beach, it runs rapidly down again under the next advancing wave. In its recoil it drags back the sand and the gravel with a loud rattle or hoarse roar, sometimes audible for many miles, as the stones of the shingle are ground over each other.

15. The force with which such *breakers*, as they are termed, fall upon the land has been measured and calculated. An undulation, or "roller," of the ground-swell twenty feet high has been computed to fall with a pressure of about a ton on every square foot of surface exposed to its reach. In summer the average force of the Atlantic breakers on the west coast of Britain amounts to about 611 lbs. on the square foot; in winter the force is more than three times as great. On some occasions a pressure of as much as three tons and a half has been recorded. Some of the effects of the action of waves upon the land will be referred to in the next Lesson.

16. (ii.) **Currents.** Since the sea responds so sensitively to every movement of the air, we may expect to find that as there is a regular system of circulation in the atmosphere, so there must be a corresponding system in the ocean. That this is really true has now been made

clear by observations in all parts of the world. The sea has been found to be in continual circulation. Such evidence as that given in Article 5 makes the reality and extent of the surface-movement readily apparent. Those superficial parts of the sea which have a regular, continuous, onward motion, are termed "currents." They are called superficial because seldom more than 500 feet deep, which is but a small fraction of the depth of the total liquid mass over which they move.

17. The current-system of the sea presents in its leading features great simplicity. It arises from the action of the great atmospheric currents, which, steadily blowing on the surface of the sea, drive its waters before them. So that if we clearly follow the course of the circulation of the air, we need have little difficulty in understanding that of the sea. The general features of the circulation of the oceans are shown in Plate VIII.

18. The trade winds set the surface-water of the sea in motion, so that it acquires a gradual tendency towards the equator. On the north side it comes from the north-east, on the south side from the south-east. Uniting along the equatorial belt, it necessarily assumes a westerly direction, and crosses both the Atlantic and Pacific oceans as the *Equatorial Current*. In the former ocean it appears not to exceed about 300 feet in depth, and to move with a surface rate of not more than eighteen miles a day.

19. Were there no land to interfere with its flow, this Equatorial Current would pass round the globe as a continuous stream of warm water. But owing to the position of the continents across its path it is broken up and made to diverge in different directions, each of the independent branches receiving a distinct name. Thus in the Atlantic Ocean, setting out from the African coast, it crosses to the American side, where, striking against the projection of Cape St. Roque, it splits into two. The smaller branch

turns southward as the *Brazil Current*, skirts the coast as far as the mouth of the La Plata, whence it bends eastward, once more crosses the Atlantic towards the Cape of Good Hope, and turns northward along the west coast of Africa, until it is drawn again into the great equatorial current. The larger branch sweeps round the northern coast-line of South America in the Caribbean Sea and the Gulf of Mexico, whence it issues through the Florida Strait as the warm and rapid ocean-river well known by the name of the *Gulf Stream*. After emerging from the narrows, with a maximum surface temperature of 80° Fahr. and a rate of 70 to 120 miles a day, this current runs parallel with the coast of the United States, but separated from it by a cold current, which descends from the Arctic seas. It gradually lessens in speed, and begins to spread out and to turn north-eastward. One portion, getting thinner and cooler, but yet retaining a higher temperature than that which is proper to the latitudes, and joining the general surface drift of the Atlantic water towards the north-east, extends to the coasts of Britain and Norway, and is said even to be traceable beyond Spitzbergen ; the other turns southward between the Azores and the coast of Spain, bends round the north-west shores of Africa, and then getting once more within the influence of the trade winds, is again sent across the Atlantic.

20. Within the wide circuit embraced by the second or south-eastern branch of the Gulf Stream lies a vast area of comparatively still-water, over the surface of much of which dense masses of sea-weed grow. This tract is known by the name of the *Sargasso Sea*.

21. In the Pacific Ocean the equatorial current has more room to develop itself. Starting from the western coast of the American continent, it streams westward across the whole breadth of that vast ocean, encountering

on its way only the obstruction of scattered islands and submarine banks. It reaches the eastern margin of Asia where that continent is flanked by the islands of the Malay Archipelago. Hemmed in there, it divides into two main branches, one of which turns northward as the warm, rapid, and river-like *Japan Current*, and sweeps along the east coast of Asia as the Gulf Stream does along that of North America. The other and larger branch forces its way into the Indian Ocean, and joins the westerly equatorial current there.

22. These movements of the equatorial waters could not be carried on without drawing the water of the northern and southern hemispheres into the general circulation. Thus in the Pacific Ocean, which is open to the south, there is a general northerly set of the cold southern water. A broad current or drift pours into the hollow of the western coast of South America and passing northwards joins the equatorial movement. Part of it, however, strikes the promontory of Cape Horn, round which it sweeps as a well-marked current. Since the Pacific basin is almost closed at its northern margin, no great current of warm water can pass northwards through Behring's Strait, and on the other hand no considerable body of cold water can escape from the Arctic Sea, although a cold current does issue from the Strait and pass down the west side of North America. In the Atlantic basin, however, where the opening into the polar region is much wider, and where the prolongation of the Gulf Stream bears its warmth far within the Arctic circle, there is an opportunity for the cold water of the Northern Ocean to make its way southward in return currents. One of these flows down the east side of Greenland, another descends from Davis Strait and pursues its course southward along the American coast, interposing between the land and the warm Gulf Stream, and partly passing actually under that current.

[illegible] across the [illegible] Stream as far [illegible] prove that the cold [illegible] with a sensible [illegible] The recent soundings [illegible] the Gulf Stream between [illegible] with a temperature of 70° Fahr. [illegible] about seventy fathoms in [illegible] the tem-[illegible] lower than 40° Fahr. [illegible] New York this cold water [illegible] from the surface, while [illegible] of Nova Scotia it comes [illegible] the surface Arctic [illegible]

[illegible] surface-currents, which are [illegible] the waters of the [illegible] by a slower motion, [illegible] and from the equator [illegible] general "creep," or [illegible] by the temperature [illegible] Lesson XI. The very remarkable [illegible] under the equator the [illegible] a comparatively [illegible] warmed by the sun, and that [illegible] as low as in the Antarctic [illegible] no transference of cold [illegible] the temperature there [illegible] But the presence of cold [illegible] of the surface shows [illegible] movement from [illegible] under the surface-currents, [illegible] the North Atlantic, carry the warm [illegible] the cold polar tracts. The cause [illegible] of the cold water is not yet well [illegible]

24. (iii.) **Tides.** One of the most remarkable and regular of the motions of the sea was alluded to in Art. 6, as that alternate rise and fall of the water called the tides, the coincidence of which with the position of the moon could not but be noticed from the earliest times. To understand this motion, we must bear in mind that while all the members of the solar system mutually attract each other, there are two which specially influence our earth—the sun by reason of its vast size, and the moon on account of its nearness. Each of these two luminaries exercises a strong attractive force upon our planet, the tendency of which is to pull out the side of the earth which is opposite to it. The solid part of the globe resists the strain, but the liquid ocean, unable to do so, is drawn outwards so as to be heaped up on that side where the attraction is exerted.

25. On the other side, too, where the distance from the attracting body is greatest, and the force of attraction therefore least, the water is not drawn away but remains behind, forming another vast swelling, the summit of which is exactly opposite to that on the near side of the earth. Were there no land to interfere with these motions, the distortion produced by this cause would give the form of an ellipsoid to the liquid mass covering our planet, its longer axis pointing to the moon. Were the earth and the other members of the solar system at rest, the two swellings of the ocean surface would remain stationary. But owing to rotation, these protuberant masses of water are forced to travel rapidly round the globe.

26. Let us fix our attention on that side of the earth which happens at the time to be facing the moon. Owing to the earth's rotation combined with the moon's own motion, our satellite appears to be revolving round the earth in about twenty-five hours. The outward bulging of the ocean-surface, which is caused by the moon's attraction

must therefore follow the moon, and run completely round the earth in about twenty-five hours, and the swelling on the opposite side of the earth must take the same course. Each of these two uprisings is felt, at every place which it passes, as a broad undulation or wave which appears once a day, or more exactly in every 24 hours 50 minutes, that being the length of the interval between each appearance of the moon on the meridian. Thus in that interval there are two times of *high-water* or *flood*, and two times of *low-water* or *ebb*.

27. It is not, however, the moon alone by which the water of the sea is affected in this way. The sun, too, draws the ocean-surface outward; but this influence, which has about one-third of the force of the moon's, is combined with the latter in the production of the broad tidal undulation. When the sun and moon are in the same line, which happens at new and full moon, their combined attraction must evidently most powerfully draw out the surface of the sea, while at the quarters of the moon their respective influences partially neutralize each other.

The accompanying figure (Fig. 19) shows how this effect is accomplished. The highest rise and, of course, the lowest fall of the tidal undulation must occur at new and full moon. These are called *spring tides*. The least rise and fall take place at the time of the moon's first and last quarters. These are known as *neap-tides*.

28. Since the movements of the tidal undulation depend upon those of the earth, sun, and moon, they can be measured and predicted a long while beforehand. Observations have likewise been made in all parts of the world regarding the times of high-water and the height of the tide, so that the length of time taken by the tide-wave to travel from point to point has been carefully determined. The rate of motion depends upon the depth of water and

the absence or presence of land, being most rapid where the water is deepest and has no obstructions in its course. In the equatorial parts of the Atlantic Ocean it exceeds five hundred geographical miles in the hour. It is estimated to take fourteen or fifteen hours to come from the

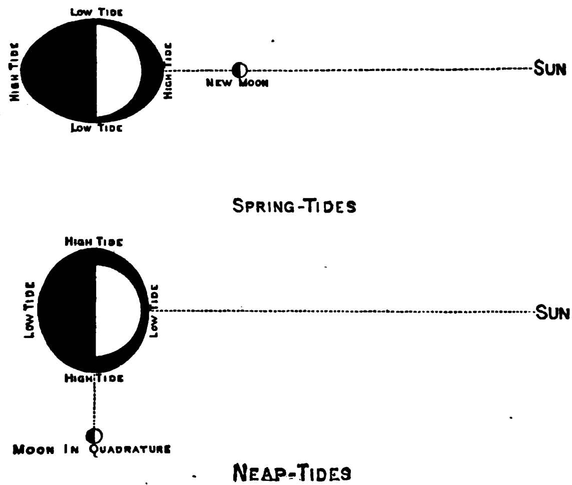


FIG. 19.—Diagram illustrating the origin of the tides.

south of Africa to the south-west of Europe, where it gets into comparatively shallow water and requires to struggle through many narrow passages. Striking the south-west of Ireland, it branches out, one part turning north along the west coast of Ireland and Scotland, then bending south along the east coast, while the other part turns to the east up the English Channel. Now the former of these branches takes nineteen hours to circle round the Brit Islands as far as the mouth of the Thames, where it m

and mingles with the wave which started twelve hour later, and worked its way in about seven hours throug the English Channel.

29. Though the tidal undulation is called a wave, an travels with great speed across the deep-ocean basins, th water itself does not partake of this onward motion. Eac particle of water merely oscillates as the rapid pulsati passes, like the stalks of corn in a field, as already cit (Art. 10). But when the undulation enters a narrow a shallow sea, it becomes jammed between the convergi coasts and experiences increasing friction against t bottom. Its rate of motion consequently slackens, but proportion as this takes place the undulation gath height and force, and becomes a true current.

30. In the deep ocean-basins the passing of the bro tidal undulation probably produces no sensible effect up the bottom. The surface of the water merely rises gen for about six hours, and then gently falls again, the to height of the undulation from low-water to high-water being more than a few inches. Thus, in the middle of Pacific Ocean the rise is sometimes less than a foot; in Atlantic, round St. Helena, about three feet. But wh the undulation meets with the resistance of converg masses of land and a shallowing bottom, it is heaped sometimes, as in the Bay of Fundy, to a height of seve feet, and rushes along as a great wave or as a surging foaming ocean-river. Thus in the Bristol Channel, wh opens towards the west, the tide rolls up a rapidly- rowing channel, and during spring-tides attains a he of forty feet in the estuary of the Severn. The adva of the tide is shown by a wave nine feet high, which ru in front, succeeded by smaller ones, until the full tide filled the estuary. This wave, or *bore* as it is ca forms a marked feature of the flowing tide in many and estuaries which open out towards the quarter wh

the tidal undulation comes. Thus on the west coast of Europe it occurs in the Elbe, Weser, Seine, Dordogne, and Garonne. At the mouth of the Seine the tidal wave enters with a speed of fifteen to twenty feet per second and a height of six-and-a-half to ten feet. The bore on the Hooghly River rushes up with such force as to do great damage to shipping unprepared for its approach.

31. When the converging shores are not closed at the end, as in the case of an estuary, but open out again into a wider sea, the tidal undulation takes the form of a rapid, river-like current, or *race*. Heaped up on the one side, it attains a higher level than on the other side of the narrow passage, though which therefore it rushes with great force and speed. The British Islands, lying, as they do, on the margin of the Atlantic Ocean, present many examples, of which the strait called the Pentland Firth, between the Orkney Islands and the north of Scotland, may be taken as one of the best. Standing at high or low water on one of the headlands overlooking that narrow passage, you look down upon a strip of blue sea about six or eight miles broad opening westward into the wide Atlantic and eastward into the North Sea. As soon as the tide begins to flow or to ebb you observe this smooth belt of water to become more and more troubled, until, when the motion of the tide is at its height, it sweeps past at a rate of eleven miles in the hour, boiling up and foaming along like some vast river. Here and there, where sunken rocks lie in the path of the current, the tumult of the water is strongest, while, should a high wind be blowing against the tide, huge waves and sheets of foam are tossed high into the air, and the whole surface of the firth becomes white with breakers. No small vessel can then attempt to force its way through the strait.

32. In other narrow passages between islands whe the tide is thrown from side to side against sunken

or where two opposing currents meet each other, the water forms *whirlpools*. Such are found in the well-known Corryvreckan between the islands of Jura and Scarba on the west coast of Scotland, where the current runs alternately east and west at a speed of eleven miles in the hour. The famous Maelstrom, at the southern end of the Lofodden Islands on the Norwegian coast, is another illustration.

33. The strip of sand, gravel or mud which is alternately covered and laid bare by the rise and fall of the tidal undulation is called the beach. When the tide is at the full, the sea reaches to the upper limit of the beach or high-water mark, when the tide is at the ebb the sea does not come further than the lower limit of the beach

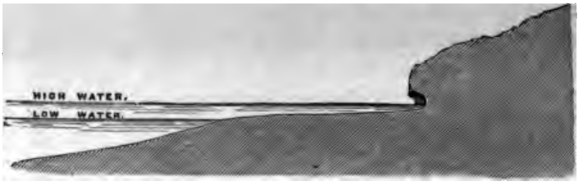


FIG. 20.—Diagram showing the relation of the beach to the lines of high and low water.

or low-water mark. The distance between these two limits must evidently depend partly upon the height of the tides, and partly upon the slope of the beach. It is of course greatest where the largest rise and fall of the tides is combined with the gentlest inclination of the shore.

LESSON XVIII.—THE OFFICES OF THE SEA.

1. In the foregoing Lessons the more important purposes which the sea serves in the general life of the earth have been described. Let us here consider them in a brief summary.

2. (i.) **The sea supplies most of the moisture of the atmosphere.** Were the air overlying the land dependent for its moisture solely upon the evaporation from the land underneath, rain and dew would almost cease, and neither vegetable nor animal life could flourish. The clouds which overspread the sky and discharge their rain-showers upon the ground, the springs which feed the brooks, the innumerable streams which go to swell the bulk of the great rivers, the snows which overspread the higher mountains, the dews which refresh the surface of the earth even in tracts where no rain falls, all come directly or indirectly from the sea. In spite of the enormous volume of fresh water which is continually poured into the sea by innumerable streams, no change of the sea-level is perceptible. That water is evaporated again, rises into the air and is borne along by the winds, till it is condensed and discharged upon the land.

3. The influence of the sea upon the moisture of the air is well shown by the much greater rainfall of maritime than of inland tracts (Lesson X. art. 29). The air lying over the sea is probably for the most part not far from the point of saturation, so that when it moves away landwards it is ready to part with some of its vapour as soon as it meets with a mass of air or of land colder than itself. Near the coast of India the evaporation from the sea is said to amount to about three-quarters of an inch in the twenty-four hours, or nearly twenty-three feet in the year. In the Red Sea a layer of ei-

feet of water is believed to be annually driven off by evaporation. A rough estimate gives a depth of fifteen feet as annually evaporated from the trade-wind region of the oceans.

4. In the torrid zone, where the evaporation is greatest, much of the moisture raised from the sea undoubtedly falls back into it in those heavy and continual rains which characterise that belt of the earth's surface. Some of it goes to supply the heavy rainfall of such regions as the Khasi Hills (Lesson X., art. 31), the Himalaya, and the high lands of Abyssinia. Very little of this equatorial vapour, however, can pass over to the temperate regions on either side, because the air which contains it, after discharging heavy showers in the zone of constant precipitation, ascends into the high regions of the atmosphere as a cold and comparatively dry current, travelling away from the equator, and reaching the surface of the earth again, ready rather to take up moisture than to part with it.

5. In Europe the rains are supplied chiefly by the moist winds which drink up the vapour of the warm surface of the Atlantic; west, and especially south-west, winds are wet, east and north-east winds are dry. The vast cauldron of the Indian Ocean furnishes the rains of the south of Asia and the east of Africa. When the south-west monsoon blows, it bears the vapour of that ocean to India and China, and discharges it in deluges of rain. The large rivers of western Africa are supplied by the monsoons, which bear the vapour of the Atlantic into the interior of that continent. In North America the mountainous western sea-board derives its moisture from the moist winds which blow from the south-west across the Pacific Ocean. In South America the south-east trade-winds carry the vapour of the South Atlantic across the continent, until they discharge the last of it on the slopes

of the Andes, and pass over to the Pacific coast as dry, rainless winds.

6. (ii.) **The sea regulates the distribution of temperature.** Its currents carry the heat of the tropics to warm the regions lying towards the pole; while, on the other hand, they bring the cold of the poles to temper the heat of the lower latitudes.

7. This general influence of the sea, well illustrated by the charts of isothermal lines, has been referred to in Lesson IX., art. 15, and the cold and warm currents of the North Atlantic Ocean were given as examples. The heated water of the Gulf Stream turns north-eastward and crosses the Atlantic, spreading out over a larger surface and losing heat as it advances, yet distinctly traceable by its warmth even into the Arctic seas. The average winter temperature of the sea round the British Islands is considerably higher than that of the land. But as already remarked (Lesson XV. art. 2) it is not directly by contact with the land that the sea tempers the climate. It warms the air overlying it, which then passes on and carries the warmth across the land. And here we see the advantage to the west of Europe in that spreading out of the Gulf Stream water which has been referred to. Were this current to pass across the ocean with the same breadth and speed which it has when it issues from the Florida Strait, even though it should retain its highest temperature, it would be too narrow to produce much effect on the climate of Western Europe. But by widening out over a far larger area and moving much more slowly, it exposes a much greater surface to the south-westerly breezes, which, warmed and ned by it, pass over to Europe.

The extent of this amelioration of the climate in rn Europe may best be seen by comparing the temperature of places on the same lati

Hammerfest, the most northerly seaport in the world, is open even in January, while to the west, on the same parallel of latitude, the east coast of Greenland is covered with snow and ice, and the sea remains frozen in vast floes even during summer. Still further south the harbours of Glasgow and Liverpool are not only never frozen, but enjoy a mean annual temperature of 47°—51° Fahr. On the corresponding latitudes in North America the coast-line of Labrador is cumbered with ice all the year. Even at St. John's, Newfoundland, which is two degrees further south than Liverpool, the harbour has been closed with ice in the month of June.

9. These contrasts, which are probably the most striking of the kind anywhere to be found upon the globe, do not depend wholly upon the influence of the warm Atlantic current in raising the temperature of Western Europe. They are partly caused also by the influence of the cold Arctic current already described as descending from Davis Strait, keeping close to the American coast and depressing the temperature there. Even as far south as lat. 44°, that is, on the same parallel as the south of France and north of Italy, the water which washes the shores of Nova Scotia is not more than five or six degrees above the temperature of thawing ice.

10. In the southern hemisphere, where sea so largely predominates, the climates are distributed with considerable regularity according to latitude. In the northern hemisphere, however, where the equalizing influence of the sea is opposed by the existence of large masses of land alternately heated and chilled, no such regularity exists. And yet even there the tempering action of the sea makes itself sensible along the borders of the land, where neither are the winters so intensely cold nor the summers so hot as they are inland. Hence a continental climate is one of extremes—great heat in

summer, severe cold in winter; an insular climate is more equable—a distinction well brought out by comparing the summer and winter temperatures of Ireland with those of regions on the same latitudes in the midst of the continent, such as the heart of Russia. (See Lesson XXXI.)

11. (iii.) **The sea wears away its shores, and thus tends to reduce the area of the land.** No one can watch the action of the waves (Lesson XVII. art. 14) without being well able to realize how powerful it must be in the destruction of even the most rocky coast-line. The mere weight of so many tons of water as are suddenly thrown by a huge wave against the land during a storm suffices to loosen and detach fragments of rock. In a subsequent Lesson we shall trace how even the hardest rocks are apt to be split up by the action of the atmosphere. The waves, therefore, are aided in their work of demolition by the cracks and lines of weakness which the atmosphere has prepared for them.

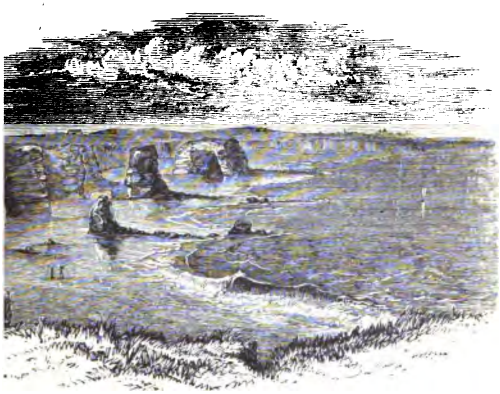
12. But the fragments of stone removed in this way become powerful implements in the further destruction of the coast-line. They are caught up and hurled forward by the waves, battering down the cliffs, and at the same time being further broken up themselves. Ground to and fro by the advance and recoil of the waves, they assume the smoothed and rounded forms so familiar in the gravel and shingle of the sea-shore. But even then their demolition continues, for they are still rolled backwards and forwards, until they become at last mere sand and mud, in which condition they may be swept away out to sea, and laid down in the quiet depths there.

13. There is yet another way in which the sea loosens a[illegible] the rocks on its margin. Those who [illegible]t on any coast exposed to storms must [illegible]ed that after a violent gale portions of

solid masonry of the pier-walls and breakwaters have been started from their places. Even with the utmost care in the building and repair of these works, it is hardly possible to avoid injury of this kind; and unless constant vigilance is used in cementing every crack and opening in the masonry, the destruction of the pier or bulwark may be rapid and complete. Now it is not by the mere weight of water thrown against the building, nor by the impact of any blocks of stone hurled forward by the waves, that the tones are started out of a piece of well-built masonry. When a large wave falls upon such a surface, the air in every cranny of the wall is driven inward. When the wave recoils again a great suction takes place behind it, and the compressed air rushes out of the masonry. Moreover, where the water is driven in with immense force so as to fill crevices and openings within the masonry, it exerts upon their walls the same pressure as the wave of which it is for the moment a part, on the principle of the hydraulic press. After a time some weak part of the work is discovered; one or more stones are loosened and then pulled out at the recoil of some large wave, so that a breach is made, which, if the storm continues, may be rapidly widened. The same kind of influence is exerted upon cliffs. Every mass of solid rock is traversed more or less by crevices which afford scope for the combined action of compressed air and waves. When the sea has drilled a cave at the base of a cliff, the action of the air alternately compressed nd released as the waves rush in and out, loosens the ock at the end and roof of the passage, so that if the iff be not too high, or the rock too solid, an opening actually made between the end of the cave and the round behind the top of the cliff. Through this opening, called a *blow-hole*, the sea when in storms sends clouds of sprav [illegible] es the mouth of the opening lies a

t distance from the edge of the sea. It is singular ind on a hill-side, or in the middle of a field or moor, ge cauldron-like hole, with the sea ebbing and flowing e bottom.

Since even cliffs of the most solid rocks are worn by the incessant attacks of the waves, we may ly believe that where the material is of less durability te of destruction must be still more rapid. On some of the eastern shores of England, where the waves gainst cliffs of crumbling clay, the rate of waste



ew of the sea-cliffs south of the river Tyne (magnesian lime-rn away by the waves, and isolated fragments left). See also

ly reaches even to as much as the loss of a yard the year. The sites of some of the former ports of Yorkshire now lie beneath the restless waters th Sea a mile or more from the present shore.

must not suppose, however, that the sea is cutting away the margin of the land. It does on those coasts which lie exposed to prevalent

storms and where the form of the shore allows the waves to act with effect. But on every coast-line there are sheltered places where the waves either do not encroach at all or at least do so very slowly. For example, if the sea is shallow for a long distance outward, with a flat sandy beach and a low coast-line, the largest waves may roll in and spend their force merely in rushing along the flat beach, and may do no damage to the shore. But in many places the sea, instead of removing material, casts it up on the land. The finer sediment swept away from one part of the coast and carried off by the currents is sometimes thrown ashore again at no great distance. When that takes place, the land may gain there as much, or nearly as much, as it loses from that part of its margin whence the sand and mud are derived. In this way the flat shores of Lincolnshire encroach upon the sea, because they continually receive some of the materials removed from the coast of Yorkshire. In many parts of the world, as along the coast of North America from the borders of Mexico to those of Virginia, and on both sides of the Madras Presidency, so much mud and sand are brought down by the rivers from the land that bars are formed, by which the land behind them is protected from the waves.

16. (iv.) **The sea receives and preserves the materials out of which new land will in course of time be formed.**—We shall trace in a later Lesson how the surface of the land undergoes continual decay. Even its hardest rocks crumble down, and their remains are swept out by brooks and rivers to the sea. In the quiet depths of the ocean-basins the sand and mud derived from the decay of the surface of the land are laid down. There they remain undisturbed, slowly accumulating and spreading, until some future movement of the earth's crust shall raise them above the level of the sea.

17. If you look into the rocks of which the present dry land is formed, you will find many of them to contain abundant remains of coral, shells, fishes, and other marine creatures. These animals lived in the sea, they were inclosed in the sediments of the sea-bottom and preserved there; these sediments, slowly consolidated into rock, have been upraised so as to form the land on which we live. What has happened so frequently in the past will probably often take place in the future.

18. Besides the deposits formed of the fine sand and mud carried away from the land, vast spaces of the bottom of the ocean are likewise covered with a slowly-gathering deposit derived from the remains of minute forms of life as described in Lesson XIV. So far as we can tell, some of the rocks of the land, the chalk of England and France for example, have been laid down in much the same way, by the gradual accumulation of the tiny shells of foraminifera and other inhabitants of the sea.

19. It is evident that while the surface of the land is subject to continual decay and removal, that portion of the solid earth which lies below the comparatively shallow depth (a few hundred feet at most) to which the influence of waves extends, is preserved. By far the largest part of the destruction which the sea works is done between tide marks. (See Fig. 21.) Waves, as we have seen, do not stir the deeper parts of the ocean, which are therefore left in undisturbed repose. When we reflect how large a proportion of the earth's surface is covered with sea, we perceive that although the waves are always beating against the shores, the destruction which they effect takes place only on some parts of the mere margin of the land, while the vast spaces under the sea are not only preserved from waste, but are continually receiving fresh deposits. So that if we consider the action of the sea as a whole, we find it to be far more preservative than destructive.

CHAPTER IV.

THE LAND.

LESSON XIX.—CONTINENTS AND ISLANDS.

1. From the two envelopes of air and sea in which our earth is inclosed we now pass to the consideration of what lies beneath or within them—the solid mass of the planet. One of the first points to be noticed here, is that while both air and sea admit of being penetrated and examined all over the world, only a very small proportion of the solid framework of the globe rises out of the sea to form land, and of that comparatively insignificant part little more than the mere surface or skin is known to us. We cannot at will pierce the land as we can sound the sea. Evidently, therefore, all that can be discovered by actual observation regarding the constitution of the solid globe must be derived from what may be seen at or near the surface of the land.

2. What then, to judge from all that can be learnt from its visible parts, is this solid globe on which we live? We are familiar with the earth and soil of the surface, and we have seen the rocks beneath it—in one country clays and limestones, in another sand and gravel, in another sandstones and shales, in still another granites and other crystalline formations. How have these various materials arisen? Can we learn anything regarding their

rigin, and do they in any way throw light upon the istory of the earth? Why, for example, should the land se into lofty ridges at one place and sink into low plains ı another; and have these ridges and plains been always ıe same as now?

3. No matter in what part of the world we may live ıch questions as these must often arise in our minds. 'he more prominent the features of the land, the more of ourse do these questions press for an answer. In a ıountainous country, for example, or one from which a istant range of mountains can be seen, the high peaks nd ridges into which the surface of the land has been hrown form so striking a contrast to the level plains below hat we cannot help at times asking ourselves how and vhen these vast elevations took their rise. We watch the louds on the far summits as they gather into thunder-torms, or dissolve into showers of rain among the valleys, r powder with fresh snow the white shoulders and rests of the mountains. There seems to be a constant urmoil in the air of these heights. What effect must t have upon the forms of the mountains? Do these ever ecurring tempests, these frequent rains and snows, which ll the torrents and feed the great rivers, leave the outlines f the mountains unchanged?

4. But even where the landscape is least marked by any triking feature an observant eye cannot fail to notice much hat is suggestive of inquiry. No scene for instance can e more monotonous than that presented by the wide plains t the mouths of large rivers. And yet when the mind is nce opened to perceive the interest of such subjects as hese, can the nature of the soil of these flat lands escape otice, and fail to be connected with the mud brought lown by the river? Whence does the mud come? How ong has the river been busy in strewing it over these lains?

5. Such are some of the questions which are now to come before us in the Lessons contained in this chapter. In entering upon them we shall do well to remember that as far as possible we should try to find illustrations of them in the district where we may chance to live. We shall not be able to do so in all, nor perhaps even in most cases. Yet the search for examples will always be of the utmost use in making us better acquainted with the physical geography of our country, and in accustoming us to the observant use of our eyes. The features of a mountain-chain, a plain, a table-land, a watershed, a spring, a brook, a river, a lake, and of every other part of the land, should be studied on the ground, wherever we can find examples of them. In all such cases, too, we should not rest content until we have put to the proof the statements regarding these features in the Lessons, and seen how far they are borne out or can be extended by what we see in nature for ourselves.

6. As the land consists of those portions of the solid globe which happen to project above the level of the sea, its distribution shows the position of the large wrinkles into which the surface of the planet has been folded, while its form and its materials must evidently furnish our chief sources of information regarding the composition and the history of the general mass of the earth. First, the distribution of the land over the globe may be noted; then its horizontal outlines or coast-lines where it meets the sea; next, its vertical outlines or relief, as it rises up into the air.

7. Distribution of the Land.—The total area of dry land on the surface of the globe has been computed to amount to fifty-two millions of square miles. It was stated in Lesson V. that by much the larger part of this land lies in the northern hemisphere. Within the Arctic Circle (Plate I. fig. 5) it forms an almost

7. If you look into the rocks of which the present dry l is formed, you will find many of them to contain ıdant remains of coral, shells, fishes, and other marine ures. These animals lived in the sea, they were ied in the sediments of the sea-bottom and preserved ; these sediments, slowly consolidated into rock, have ıpraised so as to form the land on which we live. ıas happened so frequently in the past will probably ke place in the future.

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9. But in order to have a clear notion of the ma heights and hollows on the surface of the solid globe cannot merely consider the trend of the continents. I sides these chief masses of land innumerable smal patches project above the surface of the oceans in the fc of scattered groups or clusters of islands. As these only the tops of submarine ridges or mountains tl position serves to indicate the direction of the elevati of the surface of the earth which lie under the sea.

10. In the Pacific Ocean a scattered series of isla begins to the west of the coast of Chili, and stretches the Society and Marquesas Archipelagos north-westw through the Sandwich group, and thence by the B Islands towards Japan. This long line sends off a v marked branch along the equator, taking in the Marsl and Caroline Islands, and trending north to the sout end of Japan. A third branch strikes off from Marshalls Islands to the Friendly Islands, and thenc New Zealand. A parallel chain includes the Philli and Molucca groups, Papua, and many small islets w dot the ocean as far as New Caledonia and the Islands.

11. When these lines are traced on the map the basin of the Pacific is seen to be traversed by one main r stretching from South America to Japan, with se diverging branches. It is, of course, the mountain of these ridges which form the islands. As a rule t islands do not rise much above the sea-level; the lo summits are in Hawaii, where one reaches to 13,760 The highest point of Tahiti is about 7,000 feet. Re soundings across the Pacific show an average dep between 2,000 and 3,000 fathoms, so that some poin the Pacific ridge rise as much as 30,000 feet above general level of the Pacific floor, that is, rather more the height of the highest mountain above the sea.

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the several lines upon it. In this way you will best obtain a general idea of the position of the chief ridges and hollows on the surface of the earth, and see in how curious a manner that surface has been wrinkled. Turning now more particularly to the land itself, you observe it to be defined by two limits, one where it meets the sea—that is, its coast-lines, the other where it is surmounted by the air, giving its vertical relief or contour.

16. Coast-lines of the Continents.—Though the limit between land and sea is always sharply drawn, the map of the world shows how varied and irregular it is. But even the largest and most detailed map can show only the more prominent curvings and windings of the coast-line. When such a map is carried along the edge of the land and compared with the actual boundaries of the sea, many little projections and recessions of the coast are seen which have not, and from their small size could not, find a place upon the map. Comparatively seldom does the coast continue in a straight line for more than a brief space. It curves to and fro, jutting out into *headlands*, *capes*, or *promontories*, and retiring into wide *gulfs* and *bays*, or into narrower *firths*, *creeks*, and *inlets*.

17. Besides these abundant changes in its horizontal extension or plan, the coast-line of the land presents continual variety in its vertical elevation or relief. Sometimes for example, the land rises abruptly out of the sea in steep and lofty cliffs against which the waves are ever beating. Elsewhere we find the shore shelving gently into the water. It has been observed that where the coast-line is precipitous the water is usually deep (Fig. 22), the land descending beneath the sea with the same abruptness as it rises out of it, while on the other hand a low shore commonly indicates shallow water (Fig. 23). This relation between the form of the ground and the depth of the water is so general that in navigation a vessel will usual

nuous ring round the north polar regions, whence ends southwards in long irregular masses which away into points (Lesson V. Art. 10). Each e masses of land or continents may be looked s consisting of a northern and southern division. western hemisphere they are united by a ieck of land or isthmus. In the eastern hemi- Europe and Africa are separated by the narrow nnel or inland sea called the Mediterranean. id Asia form indeed one united and continuous which is prolonged southwards by Africa on the d by a vast archipelago, or clusters and chains nto Australia on the other. In a general view y be regarded as forming three pairs of conti- nost regular being North and South America, regular being Asia and its island prolongation a.

now at the position of these continental ıy observe that there is among them a cy to run in a north-west and south-east is is specially noticeable in the case of seen, too, in the bend of the islands from n margin of Asia to Tasmania and New in the European and African pair of be traced, if we connect Greenland, by and British Islands, with the main mass can then see how an uneven and broken ds from the polar circle south-eastwards ood Hope. Hence the shape of the termined as that of a deep, long, narrow between this ridge of land on the east ridge on the west. Owing to the o the north-east, the American and lmost meet at Behring Strait, thus cific basin on the north.

rises up in cliffs and can offer a stout resistance to the waves. Wherever, on the other hand, you observe the land to retire into wide unindented bays you may suppose it to be low and to be formed of soft clays or other materials which have yielded more easily to the encroachments of the sea. In the great majority of cases your inference would be correct.

19. Compare now the coast-lines of the three pairs of continents and you will not fail to observe a remarkable contrast between those of the northern and southern divisions. The northern continents are marked by coast-lines so indented that the oceans penetrate far inland in many bays, creeks, inlets, firths, and inland seas. The southern continents, on the other hand, are distinguished by long monotonous stretches of shore, unbroken by bay or creek. The following calculation has been made of the relative proportion of coast-line to extent of surface among continents.

FIRST PAIR—								
N. America	has	1	geograph. mile	of coast-line	to	265	sq. miles	of surface.
S. America	,,	1	,,	,,	,,	434	,,	,,
SECOND PAIR—								
Europe	,,	1	,,	,,	,,	143	,,	,,
Africa	,,	1	,,	,,	,,	895	,,	,,
THIRD PAIR—								
Asia including the Islands ...	,,	1	,,	,,	,,	469	,,	,,
Australia	,,	1	,,	,,	,,	332	,,	,,

20. It will be seen that the contrast is most marked between Europe and Africa. The former continent has six times more coast-line in proportion to its superficial extent than Africa has. There can be little doubt that this contrast has had a powerful influence on the civilisation of the two continents. In the one case abundant bays and arms of the sea have offered ready facilities for discovery, conquest, and commerce. Nation has been

t These ridges, however, it must be remembered, are
ontinuous submarine mountain-chains. They are
rough by broad and deep hollows, which are even
mes much deeper than the general level of the floor
ocean. Thus the deepest sounding yet obtained
art of the sea (4,475 fathoms or 26,850 feet) was
the Caroline Archipelago.

the Atlantic basin (Lesson XII. Art. 15) scattered
ord similar indications of the general direction
es upon the solid globe. North of the equator
e bank crosses the ocean from Cape Verde
dland; its highest summits rise above the sea
Verde and Canary Islands, Madeira, and the
r elevations which do not reach up to the
submarine banks, like the Great Bank which
oundland. South of the equator a north-
of submerged ridge is indicated by the
Paul, Ascension, and St. Helena, while
to lie further south with the island of
a marking its highest point. Again, from
montory of the African continent a long
ch under the sea in a south-easterly
frozen lands of the southern pole. Its
d by the Prince Edward, Crozet, Ker-
Islands.

Ocean presents the same kind of
lid earth has an uneven surface below
e of islands and submerged banks
ascar and Bourbon northwards to
r similar line starts from opposite
d runs through the chain of the
e islands for seven or eight degrees

low these descriptions you shou

diameter of the earth; so that on a globe of ten feet in diameter the highest mountain in the world would be represented by a little projection only one-twelfth of an inch in length.

23. If, then, the most stupendous mountains are really so small, it is evident that the whole mass of dry land must form but an insignificant part of the entire bulk of the earth. For by far the largest part of the land is not mountainous. Calculations have been made regarding the probable average height of the land, if the mountains could be levelled down and the valleys filled up so as to reduce the whole to one general level. This, exclusive of Africa and Australia, has been estimated to be about 925 feet. The continents, however, differ much from each other in this respect. To Europe, for example, the great geographer Humboldt assigned an average elevation of 676 feet, while that of Asia he computed to reach 1,132 feet, and that of Africa has been put down at 1,800 feet. From these estimates it is found that even vast mountain-chains do not form such a large proportion of the mass of the land as they might be supposed to do. It has been calculated, for instance, that if the whole of the Alps could be ground down and spread over Europe, the surface of that continent would not be raised more than about 21 feet.

24. In no respect does the land stand out in more marked contrast with the sea than in the endless variety of its relief. While the surface of the oceans is one vast level, that of the land exhibits every contrast of form from the jagged peaks and precipices of the mountains down to the level flats of the meadows and plains. We are apt to see no order in this variety. Mountain and valley seem to succeed each other, and to change their shapes at random. And yet an attentive study of them shows that they have not been stuck down on the earth's

ept well away from a low shore, though brought with-
resitation close under a high headland.

Steep shore descending abruptly into deep water.

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is, its coast-lines, the ot[her] ... part of the entire
the air, giving its vertical ... largest part of the
16. Coast-lines of the C[ontinents] ... have been ...
between land and sea is al[ways] ... *of the land,*
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the largest and most detai[led] ... one general level
prominent curvings and wi[ndings] ... has been est[imated]
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projections and recessions ... assigned
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a straight line for more th[an] ... it is found
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bays, and retiring into ... they might be
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AND ISLAND

LESSON XX.—THE RELIEF OF THE LAND—MOUNTAINS, PLAINS, AND VALLEYS.

1. From what was stated in last Lesson it may be inferred that although the surface of the land is very uneven, rising sometimes, as in the Himalaya, five-and-a-half miles above, and sometimes, as in the hollow of the Caspian (3,000 feet deep), sinking nearly three quarters of a mile below, the sea-level, its inequalities are not altogether disposed at random. And this is really the case. Each continent has its own system of heights and hollows, and these are grouped in relation with the general axis.

2. The main features of the continents are the lines of mountain chains. It is along these lines that the elevation of the land has been greatest. They are, as it were, the crests of the great waves into which the surface of the solid globe has been thrown. They govern the trend of the chief valleys, they determine the position of the plains, they regulate the climate, the winds, rains and rivers, of the land. They ought first to be considered, therefore, in any description of the general aspect of a country; we may then pass to the valleys and plains.

3. **Mountains.**—The term 'mountain' is rather vaguely used to describe any large and lofty elevation rising conspicuously above the region which surrounds it. Sometimes a single conical mountain towers above a plain or shoots up from the sea. Solitary cones of this kind are usually volcanoes, such as Etna, Vesuvius, and the Peak of Teneriffe. More frequently a mountain is merely a more prominent and elevated part of a long lofty ridge and is joined at the sides to other similar mountains, into which that ridge is divided by the valleys which cross it. Such a connected series of mountains is called a

ught into contact with nation; the arts of peace and have spread into every country; no region however te has lain wholly beyond the reach of communica- with the rest; and hence all the communities of e, whether slowly or rapidly, have been carried for- y the general progress of mankind. But with this nt intercourse and steady advance contrast the n of Africa, with its vast expanse of hitherto ble and unopened territories, peopled by ing no intercourse with other tribes save their and usually hostile neighbours, and remaining immemorial in the same stationary condition of

Doubtless the noble rivers and lakes of eventually become highways of civilisation heart of the continent, and be made to serve which in old times was accomplished in far-reaching arms of the sea.

Relief of the Continents.—The horizontal asts of the land are greatly surpassed in rest by its vertical outlines or relief. It the former upon a map, but much more ly to express the latter. Hence even the imperfect idea of the external details for the next Lesson we general features which are the globe.

k of land rises but a small way the earth's surface. Think, for en the height of even the Mountains and the total Mount Everest stands level of the sea, an the little undulations hts of many hilly th of the polar

[illegible] that on a globe of ten [illegible] the world would [illegible] mountain [illegible] one-twelfth of [illegible]

[illegible] stupendous mountains [illegible] the whole mass of [illegible] part of the ent[illegible] largest part of [illegible] have been ma[illegible] height of the land, [illegible] average [illegible] and the valley [illegible] levelled down [illegible] general leve[illegible] whole [illegible] has been est[illegible] The continents, howeve[illegible] in this respect. To Europ[illegible] geographer [illegible] assigne[illegible] an average [illegible] while that of Asia he [illegible] feet, and that of Africa has been put down [illegible] feet. From these estimates it is found that even [illegible] mountain-chains do not form such a large proportion of the mass of the land as they might be supposed to do. It has been calculated, for instance, that if the whole of the Alps could be ground down and spread over Europe, the surface of that continent would not be raised more than about [illegible] feet.

[illegible] In no respect does the land stand out in more marked contrast with the sea than in the endless variety of its [illegible]. While the surface of the oceans is one vast le[illegible] of the land exhibits every contrast of form from [illegible] peaks and precipices of the mountains down [illegible] flats of the meadows and plains. We are apt [illegible] order in this variety. Mountain and valley [illegible] succeed each other, and to change their shapes [illegible] an attentive study of them shows [illegible] been stuck down on the earth's

ıce at mere hazard, but have an intelligible mean-
ınd history, and a traceable connection with each

First of all it is to be noticed, that each of the conti-
s traversed by a line or axis from which the ground
on either side to the sea. This axis does not
ily coincide with the highest parts of the land:
y lie now to the one side of it, now to the other;
he line of average highest elevation, as is shown
y in which the rivers flow from each side of it.
axis placed down the centre of the continent;
lly it is much on one side. In America, for
lies close to the Pacific sea-board. In Europe
n Cape Finisterre through the chain of the
e Alps, the Carpathians, and the Caucasus to
the Caspian Sea.
osition of the axis determines the general
r side. When it runs along the centre of a
ıngle of slope on either side will be nearly
ıen it lies close to one side the angle must
at side than on the other. Each continent
an axis lying far from the true centre of
herefore a short and steep slope on one
and gentle slope on the other. South
the most remarkable example of this
, with an elevation of perhaps 8,000 or
own the line of the Andes at a distance
100 miles from the Pacific, but 2,000
ntic Ocean. On a much smaller scale
is shown by Scandinavia, where the
Atlantic, and where consequently the
idly into that ocean from the snow-
ut slopes gently eastward across
of Bothnia. In the British Islan

separate its ridges, or ranges, are called longitudinal; those which run across the ridges and divide them into independent mountains are termed transverse. Thus the Swiss Alps contain the two parallel lines of the Bernese Oberland and the Pennine range, separated by the longitudinal valleys of the Rhone and Rhine. The former of these ranges is cut through by many transverse valleys and passes, such as the Rawyl, Gemmi, and Grimsel, between which rise massive snowy mountains. The latter is likewise deeply trenched by valleys and passes, separating some of the monarchs of the Swiss mountains—Mont Blanc, the Matterhorn, Monte Rosa, and the St. Gothard.

10. The direction of the great mountain-chains of the globe has evidently a close connection with that of the continents. Of this connection America, which in many respects is a typical continent, furnishes an admirable illustration. The long, continuous line of mountain-chain which extends from the southern spur of the Andes to the most northerly swell of the Rocky Mountains, a distance of some 9,000 English miles, coincides with the general trend of the continent, and forms the axis or back-bone of that vast tract of land. This main line of elevation in the New World runs in a general north-west and south-east direction. In the Old World a vast mountain system, with many branches, stretches from the north-east of Asia across the centre of that continent and the south of Europe to the north-western headlands of Spain—a distance of about 12,000 miles. Here the general trend is on the whole east and west. These are the two great mountain ridges of the world.

11. We shall return to the structure and origin of mountains in a later Lesson (Lesson XXIX.) after the nature and arrangement of the materials of the solid earth have been considered. Meanwhile we have to

aucasus on the south, the Urals on the east, and h grounds of Scandinavia and Britain on the west. n most cases the upheaval of the continents has omplished in such a way that these central plains rounds slope seawards. The water which falls therefore, is not retained there, but flows off to

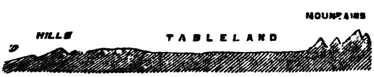
In the crumpling and erosion of the surface however, depressions have been formed upon ntinents below the level of the surrounding these the water flows, and fills them up till d discharge their surplus by means of re the numerous water-basins known as me regions the water cannot find an except by evaporation. On the high Asia a desert region of this kind, inclosed between the Hindu Kush tains, and stretches through Turk- a distance of about 2,000 miles. In smaller basin, shut in among the tains, receives its drainage into ich the Great Salt Lake of Utah the south-east of Europe the scends far beneath the level of that inland sheet of salt feet below the general level of the Dead Sea, which t in by high grounds, is Mediterranean.

tion and broad general he surface of the earth. ne of the more promi- d.

tain-range. It often happens that two or more such f mountain run parallel with each other as one l continuous mountain-chain, or mountain-

Let us consider for a little the aspect of some ountain-chain as an illustration of this feature ice of the land.

ps of Europe have been so long familiar to their name has passed into use as an appel-nain mountain-system of any country. To ches it from the north, that noble chain of reveals its characters step by step. Cross-France or Germany into the district of the ground begin to rise and sink in leys, which follow each other in parallel tions on the surface of a great ocean. re green and fertile ;. the ridges, for



of one side of a Continent.

ear their slopes of rich pasture how along their crests long s bounded by walls of rock. e gorges cross the ridges e plains beyond. Thread-rse valleys, the traveller grow higher, and the and deeper, until he these outer elevations. e side, as in a map, ll and valley across

the original table-land can scarcely be any longer traced (See Lesson XXIX.).

20. Having noted now the leading forms of surface by which the land is marked, we are led to ask whether any explanation can be given of them. How have the vast mountain-chains been formed? Have they always existed, and have their crests and pinnacles, their precipices and ravines and valleys, always been as we see them now? An answer to these questions can be given with considerable confidence and fulness, but to be able to understand it we must attend with some care to two aspects of the physical geography of our globe. 1st. The nature of the earth's interior and the reaction of the interior upon the surface; and 2nd, the circulation of water upon the land and the other external processes by which the surface of the land is affected. The next Lessons will be devoted to these two subjects, and we shall then return to the question as to the origin of the present features of the land.

LESSON XXI.—THE COMPOSITION OF THE EARTH.

1. Of what materials does the solid land consist? How are these materials arranged so as to form the vast mass of the globe? Man cannot pierce beyond the mere outer skin of the planet; can he then ever hope to learn the probable constitution of its interior? These are some of the questions to which we must now turn. In endeavouring to find answers for them let us begin with what is nearest and most familiar.

2. No matter in what part of the world we may live, the uppermost layer or covering of the land is almost always one of vegetation, in one place grass, in another forest, in another thickets of jungle or brushwood. Here and

nsider some of the other leading forms of outline which land presents.

2. Plains.—The chief flat lands of the globe lie een parallel mountain ridges; to a smaller extent occur as narrow belts, or fringes, flanking the sea-slopes of mountains or of elevated tracts. Take he American continent by way of illustration. In America a vast plain stretches between the Rocky ns on the west, and the Alleghany and White is on the east from the Gulf of Mexico up to Ocean. Of course this wide expanse of land ere dead level. It abounds with ridges of low ines of valley, but neither its heights nor its sufficiently marked to destroy its character as e enormous territory watered by the Missis- tributary rivers forms the southern and this plain, and is so flat that vessels can a distance of about 4,000 miles from the ands of square miles its gently undulating ed with grass. These tracts west of the nown as prairies or savannahs.

half the surface of Europe is a vast the heights of Scandinavia, Scotland, north-west, by the ranges of the Urals y the chains of the Pyrenees, Alps, ucasus on the south. From the west sweeps eastward across the north of , spreads out over most of Russia, epression of the Caspian Sea, passes ds northward between the Ural and s, covering there a belt of territory d, and nearly 4,000 miles long. In ie Russian plain, the soil is a dark abundant corn crops. Further

ere, indeed, where the surface is formed of shifting sand plants may be able to take root, or in rough, and cially mountainous ground, ledges and crags of bare shoot up into the air. But even in such places as we may often detect some struggling weeds or shrubs are striving to bind the loose sand together, or to odgement among the crannies of the rock.

ripping off the layer of vegetation we see below it of soil on which the plants grow. They send s down into this layer and extract from it some erials out of which their framework is built up. eatly in colour and composition, being some- grey clay, sometimes a soft, black, crumbling mes a brown or yellow sand, and sometimes be little else than a sheet of gravel. In all r, it will be found to consist of small particles ents, which appear broken or worn. These ntly derived from some solid rocks. Look magnifying-glass and you will notice this ative character still more clearly. Roots ng through the soil open it up and per- pass into it, while the common earth- s in this work, and brings up lower o the surface.

is more or less organic matter, besides rth, or clay. You drive this off by n so doing you deprive the soil of its nic matter is derived from the plants and animals, and is made When a farmer has cultivated his ich successive crop has taken so of the ground that in the end sted that it needs to have fresh n the form of manure before it

been accumulated to depths of many thousand feet. The now frequently form lofty ridges of mountains. Th spread also over the lower grounds; most of the wi plains of the world have rocks of this kind below the

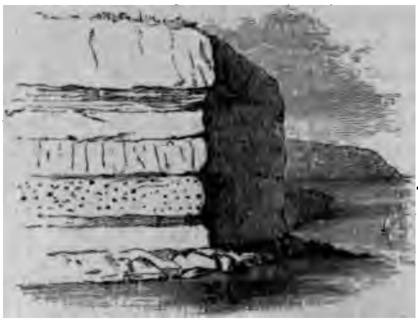


FIG. 26.—Bedded arrangement of rocks. (a) conglomerate; (b) sandstone (c) shale.

One of their most obvious features is their arrangement in layers, beds, or strata, which vary in thickness from less than an inch to several feet or yards, and are piled regularly above each other. Hence a cliff of these rocks has a striped or banded look (Fig. 26). They are known as bedded or stratified rocks.

10. Together with these there often occur other rocks formed wholly or in great measure of the remains of plants or animals. For instance, amid a mass of sandstone and hardened clay you will occasionally come upon traces of the fronds of ferns (Fig. 27), and the seed-cones, leaves, stems, and roots of other plants. These vegetable remains sometimes have been so crowded together that they form black or brown seams of coal, and in that condition supply much of the fuel which man consumes at the present day.

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eruptions of volcanoes—the molten rock known as lava being one form of the crystalline rocks.

15. There can be little doubt that the rocks of this second or crystalline series have come from below, and have been thrust in a melted state among the other rocks, or have been poured out at the surface as lava. Hence we must infer that beneath the outer layer of stratified or derivative rocks, though it may be many thousands of feet in thickness, there must be an inner layer or mass of crystalline material which has here and there been squeezed through the stratified rocks, as in the axis of mountain-chains, or has communicated with the surface by means of the openings of volcanoes.

16. So far our conclusions are founded on what can be actually seen. They may be regarded, therefore, in the light of established truths. We have traced the materials of the solid earth from the thin outer layer of surface-soil down through the thick piles of stratified sandstones, clays, limestones, and other rocks into the still lower granite, lava, and other crystalline masses. We have seen that by some means the materials of the land have been raised up out of the sea, and that portions of the underlying crystalline rocks have actually been pushed up into the very heart of the mountains. Can we descend any further and trace still deeper layers in the structure of our planet? Not directly; no distinct lower portions have come through the crystalline rocks. Nevertheless, enough evidence may be gathered to indicate with some probability what lies still further down.

17. Most of the rocks at the earth's surface weigh from twice to thrice as much as water. In other words, their specific gravity is from 2·0 to 3·0, that of pure warer being reckoned as 1·0. Experiments made with the pendulum and the plumb-line on the earth's attraction, indicate that the weight of the planet is about twice as

'e in the north-west of Spain some of the springs
perature as high as even 192°. All these places
from an active volcano, but it may often be
t hot springs rise along mountain-chains or at
where the rocks have been intensely crumpled
ey may have been greatly heated during the
Here and there, as will be pointed out in the
the remains of volcanoes occur which are
and silent, and from which no eruption has
thin the memory of man. Yet some of
anoes are still associated with hot springs.
olcanic district of Central France, for
's springs occur, sometimes with a tem-
h as 174°.

nost remarkable kinds of hot springs,
t heat of at least some parts of the
hose which throw out their contents
occur in volcanic districts and are
t being the local name borne by
1 were first described. The part of
hiefly occur is a space about two
ide valley among volcanic rocks.
ground is pierced with abundant
of steam and hot water escape.
be nearly 100 in number, are
sin-shaped rims or mounds of
coloured incrustations of silica,
e hot water. They vary in size
nches across, up to huge caul-
which rises fifteen feet above
-six feet in diameter. In the
Geyser a pipe or funnel, eight
th. From this opening boil-
g into the basin and flowing

illy fill again, the rumblings and jets of water and begin anew, until next day another grand outburst s the geyser.

The Yellowstone National Park, in the Territories 'nited States, contains several hundreds of geysers l over a wide tract of country. Many of these are their rims and basins of siliceous incrustations out above the ground to mark where the boiling e rose. Some exceed the Great Geyser of Iceland d in the height and volume of water and steam r discharge when in eruption.

other interesting series of geysers occurs in New here also active and extinct volcanoes are met spouting hot springs of Orakeikorako gush nbers on either side of a river-valley, while at e water is so largely charged with silica that it a series of terraces and basins down the side itous bank from near the top of which it takes

'olcanoes form so interesting a part of the y will be described in some detail in the *son.* Let us note here that they are openings eam and other hot vapours as well as streams are discharged, that they occur in many orld, and that they prove that within the rock exist at a white heat.

n, then, from such evidence that the earth an enormously high internal temperature. as arisen as to whether the interior is Some have maintained that the earth *ll of* molten material with an exterior een variously estimated at from twenty les in thickness. Others have insisted constituted could not rotate as the earth globe must be solid to the centre.

29. If the heat goes on increasing at the same rate as it is observed to do in the comparatively shallow borings which man can make into the earth, the ordinary melting-point of even the most refractory substance would, as we have seen (Art. 21), be met with at a comparatively short depth beneath the surface. But it does not follow, therefore, that the materials of the interior should be actually in a state of fusion. We know that pressure has the effect of raising the melting-point of such substances as those which form most rocks, that is, it keeps them from melting until a still greater heat is applied. The pressure at great depths within the earth must be enormous. Hence below a depth of a few miles, where the temperature reaches the ordinary melting-point of most rocks at the surface, each successive layer of the earth's substance may not be actually fused but may be just at the melting-point proper to its depth. The whole globe might thus be solid, but the least diminution of pressure at any point would allow the parts so relieved to melt at once. This, so far as can be judged, seems to be the most probable condition of the interior of the earth.

30. The internal heat being so great, there seems no reason why the innermost parts of the planet may not consist of metal, such as iron or gold. And indeed there is some reason to infer that they are really metallic. Cracks have been made abundantly through the rocks forming the land, and in many of these metallic ores occur which are believed to have not improbably come up from a metallic region below. Researches into the constitution of the sun and of the other planets have tended to confirm this view of the metallic composition of the central parts of the earth.

31. Summing up what has been said in this and previous Lessons regarding the constitution of the globe, we find that beneath the outer envelopes of the atmsophere and the

PLATE . IX

being marked by the depth of shading.

times.

the solid earth has an upper layer of loose, crumbled erials—gravel, sand, and mud on the sea-floor, soil 1 the land—under which lies a thick series of stratified derivative rocks; that still further down masses of talline rocks, which have in many places been forced ugh the overlying series, descend to an unknown h, and that within them there may be a metallic central s. We see, moreover, that since the heat rapidly in- ises as we descend, the innermost parts of the globe it have a temperature far more than sufficient to melt y known substance and even perhaps reduce it to the e of vapour, but that the pressure of gravity may be it enough to retain the general mass of the globe in a d state, except at such places as supply the streams of ten lava which flow from volcanoes.

LESSON XXII.—VOLCANOES.

. Reference has been made in previous Lessons to canoes and some of their characters. We are now to dy them more in detail. The word volcano is derived from lcanus, the name of the Roman god of fire, who was sup- ed to have his subterranean forges at the roots of the untain Etna. It is applied to any conical mound, hill, or untain, formed of materials which have been erupted m beneath the surface. When it is *active* it emits ses, steam, water, mud, dust, stones, or molten rock m its summit, or from fissures or other openings on its es. The term *volcanic action* is used to describe the kind of work done by a volcano. A volcano may *dormant* when it remains a long time without giving y of the usual signs of volcanic action; and it is said be *extinct* when, though its external form may

retained, it has never been known to be active and does not seem to have been so for a great many centuries.

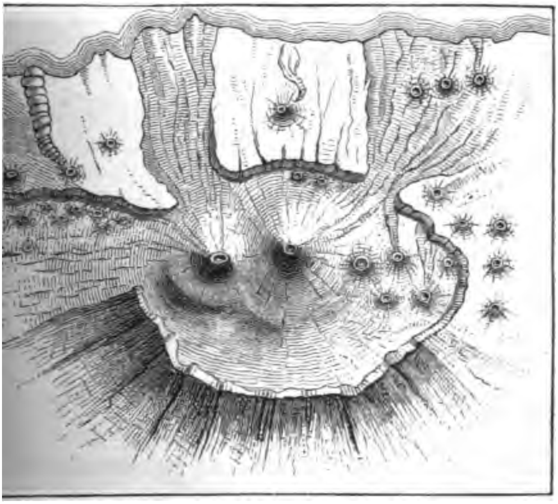
2. The size of a volcano varies from a mere little mound a few yards in diameter, like some of the mud-volcanoes around the Caspian Sea, up to a giant mountain like Cotopaxi, which rises among the Andes to a height of 18,887 feet above the sea, its upper 4,000 feet forming a smooth snow-covered cone with an orifice at the top whence hot ashes and stones are scattered far and wide over the surrounding country.

3. At the top of a volcano lies a basin-shaped hollow called the crater, from the bottom of which the pipe or shaft descends, whereby the volcanic products are brought to the surface. Vast showers of fine dust and stones are frequently thrown out from most volcanic craters. These materials falling down the slopes of the cone gradually increase its diameter and height. In like manner streams of molten rock called lava, issuing either from the lowest part of the lip of the crater or from some fissure or orifice on the side of the hill, pour down the slope and harden there, thus still further augmenting the bulk of the volcano.

4. As a volcano increases in size, and cracks are formed in weak parts of the cone, smaller cones are piled up on its flanks by the emission of dust, stones, and lava from these fissures. A large volcanic mountain, like Etna, or the Peak of Teneriffe, is thus sometimes loaded with small volcanoes which often reach a height of five or six hundred feet. In the drawing (Fig. 32) a plan is shown of one of these great volcanoes with its groups of minor cones.

5. At the beginning of a volcanic eruption rumblings are heard like the muttering of distant thunder, while the ground is felt to tremble slightly. These noises and tremors increase in intensity, successive loud explosions take place in the pipe of the volcano, and at last clouds

e dust and steam are hurled with prodigious force p into the air. The steam rapidly condenses into which falls in torrents down the outer slopes of the ıtain. The fine dust is sometimes given out in such tities as to darken the sky for many miles around. ıe famous eruption of Vesuvius, which in the year 79 ·oyed the Roman cities, Herculaneum, Pompeii, and



ıG. 32.—Plan of the Peak of Teneriffe, showing the large crater, partly effaced, and smaller craters with lava currents issuing from them

ıbiæ, the air was as dark as midnight for twelve or een miles round, and a thick deposit of fine ashes and ınes fell on this whole district. Some notion of how mpletely this eruption of ashes covered the country may obtained from the accompanying drawing, which

represents one of the streets of Pompeii as it now appears, after the volcanic deposit under which the city lay buried for sixteen centuries has been cleared off. At the further end of the street where the excavations have stopped, the dark layer on the top of the walls, and on which the pine-tree is growing, represents the thickness of the general

FIG. 33.—View of a Street in Pompeii.

covering of volcanic ashes. The finer dust, carried up into a strong upper current of air, is sometimes transported for hundreds of miles before sinking to the ground. Illustrations of this kind of transport were cited in Lesson XI. to prove the existence of these upper currents in the atmosphere.

... as seen from Naples during the eruption of ...

... destruction. Prior to the first ... that mountain was a dormant ... had ever been known ... crater on its summit, ... and wild vines, like the

troni and some of the other extinct volcanoes s (see Fig. 5). Suddenly in the year 79, when ruption took place which destroyed Pompeii, estern side of the cone was blown away and ne of much smaller dimensions was formed circuit of the former crater. In the drawing us (Fig. 35) as seen from the sea, the semicircle ld crater appears behind the modern diminished

no doubt by the enormous expansive force of

35.—Mount Vesuvius as seen from the sea, with the remaining part of the old crater of Somma behind.

imprisoned water and steam, that the molten lava is ced up the pipe of the volcano. After the first exsions, lava is seen to flow either from the top or from e or more points on the side of the cone. Should the les of the mountain be solid enough to resist the enorous of the ascending column of lava the latter nd no escape until it fills up the crat

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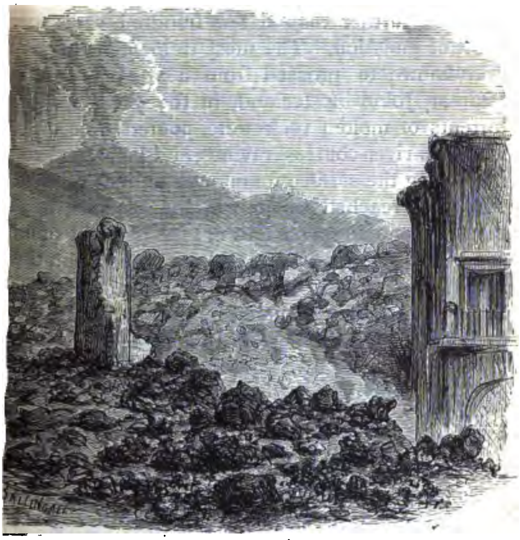
eam and acid vapours which are coming off abun-
' from the molten rock. Trees, walls, gardens, and
ırds are successively buried under the burning flood.
ıse or range of houses may form a temporary barrier;
'entually these buildings are pushed over like mere
s of card and engulfed (Fig. 36), or the lava is piled



ı.—Houses surrounded and partly demolished by the lava of Vesuvius, 1872.

st and passes round them, meeting again below so
'e their highest points, perhaps, projecting from the
f a rugged sea of lava. It sometimes happens
sti... k inside bursts through the hardened
front and pours down in a ne

rface of the current was everywhere quite

e lava begins to flow freely from a volcano he eruption usually abates. The showers lly cease, or at least do not extend beyond its immediate vicinity. The explosions an rumblings disappear, and except for the s always hanging over the summit of the which marks how constantly and abundantly ntinues to rise from the crater, nothing at to indicate from a distance that volcanic extinguished, but merely quiescent for a time. the summit of the cone at such an interval that hot vapours and gases still keep stream- m the summit and sides of the mountain. y after an eruption of Vesuvius it is observed ge destruction takes place among hares and he hill-sides, owing to the plentiful emanation sonous carbonic acid gas. Many centuries after c district has ceased to be subject to any erup- gas continues to rise, sometimes in large quan- ther bubbling through the water of springs or out of crevices in the ground.

The number of active volcanoes on the surface globe is computed to be about 173. These are istributed at random, but follow certain lines, as n in the map on Plate IX. It will be observed that e lines generally coincide with some of those ridges he surface of the earth which have been already referred n Lesson XIX. Almost all volcanoes are thus ranged one or other of the great ocean basins. The nd island barriers which encircle the Pacific ne vast ring of active volcanoes. Beginning le we find in the giant chain of the Andes a e volcanoes, some of them the loftiest on th

uth Shetland Islands, and to extend even into the
ed Antarctic continent, where, amid the vast snow-
f that region, Sir James Ross in 1841 discovered an
'olcanic cone 12,369 feet high.

3ut besides these active volcanoes there is a still
ıumber which are either dormant or extinct. It
 seem that few large tracts of land exist where
: may not be obtained of former volcanic action.
'eams and consolidated beds of volcanic dust may
l in almost all countries. Sometimes, indeed, as
al France (Fig. 37) the cones are still as fresh as if
l been thrown up only recently ; and yet no record
that they have ever been in eruption within the
human history. Hence if to the present long list
volcanoes we add those which are now extinct,
find the whole surface of the land to be studded
points of volcanic eruption.

hen we consider that each of these points marks
: at which highly-heated materials have been
rth from the interior, and that they are so widely
d over the earth's surface, we see how important
'idence as to the high internal temperature of the
son XXI., Art. 27).

vas pointed out in the last Lesson (Art. 29), that
interior of the earth is probably solid as a whole,
on of it, beyond a depth of a few miles, is probably
ing-point and ready to pass into a liquid condition
diminution of the pressure takes place. The
he surface of the earth, formed, as they have
ıg the contraction and consequent general sub-
the outer parts of the planet, have doubtless by
e relieved the pressure upon the parts under-
ı. This relief has probably allowed portions of
to pass into the state of fusion. You observe
tiv of the globe are mostly arrange

ıch lines of elevation, whether on a continent as ı America, or in chains of islands as in the western ·thern sides of the North Pacific Ocean. This nent can hardly be accident. It helps to connect tion of the land and the phenomena of volcanoes ng how we should expect large spaces of melted e under those very regions where active volcanoes /olcanoes do not pierce every mountain-chain, though in some cases they can be shown to have :ed but to have been long extinct.

e reservoirs of molten rock may exist underneath iving rise to actual volcanic explosions so long ;age is opened to the surface. When water de- rain, rivers, lakes, or the sea, filters through rocks and eventually reaches these deep, in- : regions it is raised to a very high temperature, he white heat of the molten rock with which it contact. When portions of this superheated :eed in effecting their escape, their removal : pressure on the mingled mass of molten rock ›elow, which is then forced upwards, and, where ıds an exit to the surface. It is these subter- ements which give rise to the explosions, ashes, lava-streams of an active volcano.

r XXIII.—Movements of the Land.

:ceding Lesson some account was given of the h volcanic action affects the surface of the ıg certain lines or at certain points where com- ıas been opened between the surface-waters ısely hot materials below, showers of dust and streams of melted rock have been emitted ı form huge mountains like Etn

[illegible]

Frequently [illegible] spreads [illegible]

[illegible] death and ravag[illegible]

[illegible] states.

...r, we regard earthquakes as part of ...ure, it is not so much their influence ... property as their permanent effects ...e land which claim our notice. An ...simultaneously over the whole region ...ins at one side or end, and travels ...r it is experienced first and most ...ain central space, from which it ...ons, getting feebler as it diverges. ...roach, like that of distant thunder, ... waggons, may precede by a few ... the earthquake itself. When the ...nd is felt to be alternately raised ...ore or less violence, as if an un...nd-swell of the sea were passing ...cks in succession, but commonly ...he first, may follow within a few

...s really of the nature of a wave ...bstance of the solid earth. Just ... rest in a harbour are seen to rock ... of the sea rolls under them, so ...ects have been observed to sway ...s during an earthquake.

...nd cliffs, large masses of clay or ...sengaged and sent rolling down ...or valley below. The streams are ...rary lakes are formed, until, by the ...of fallen debris, the water rushes out ... rries another kind of devastation

... the ground has been seen to be ... thus formed sometimes swallow ...r objects on the surface and close ... they remain open and are subse-

h a front sometimes sixty feet high, not only
? beach but even sweeping far in upon the

a-wave does not travel so fast as the earth-
Hence it arrives at a coast some time later
the destruction. This was the case in
rthquake of 1755, by which Lisbon was
again in 1868, when Peru and Ecuador
by a disastrous earthquake. On the 13th
latter year a great sea-wave inundated
ica, the principal port in the south of
inutes every vessel in the harbour was
ked, or floating bottom upwards. A
ept inland for a quarter of a mile.
peared, and no vestige of it was ever

of earthquakes is not yet well under-
take their rise from more causes
ay sometimes be due to the giving
cavities which no doubt exist in
especially in volcanic countries,
of rocks under great strain, or
or escape of steam. Whatever
gin, some sudden blow within
will account for the pheno-
he point directly above that
n suffers the severest shock,
as the waves travel outwards
s propagated from the point
ill water which is struck by

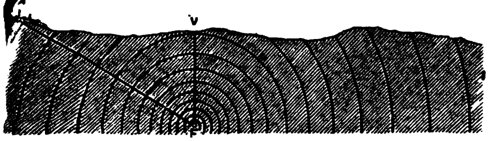
as passed, the point can be
was vertical, and if, by
direction of the rents in
3), it can be determined

...long the path indicated ...
... vertical, we obtain ...
... Calculations of this ...
who concludes that ...
...seated, but ...
... thirty geographi...
... the successive wa...
... whence they spre...

tions through the solid earth, becoming less
lent as they recede.

quakes, as represented in Plate IX., are most volcanic districts, though not by any means them. The great earthquake region of the stretches from the Azores along the basin of ranean into the heart of Asia. In the New western border of the Continent suffers most akes, especially from Guatemala southwards ador, Peru, and Chili.

rea convulsed by a single earthquake is often s been computed in the case of the Lisbon to have stretched over a region four times



am-section to illustrate the propagation of an earthquake-wave f the mode of calculating the depth of its origin.

tent than Europe. The earthquake of the 13th , was felt in Peru for a distance of 2,000 miles.

heaval.—After an earthquake has ceased the netimes found to have been raised above or neath its previous level. But besides these violent movements others have affected s of the earth in such a slow and quiet t to be perceptible at the time, but to be ection by observation of their effects at the

land.

bour- ... lls are sometimes found t s ... even the highest tide.

ht of 1,300 feet above the sea, where sea-shells, position, attest the amount of uprise.

By evidence of these various kinds it has been ained that many long tracts of coast-line are slowly from the sea. Thus the shores of Sweden at holm and northwards appear to be upheaved at a varying from six or ten inches to two-and-a-half in a hundred years. Further north the island of

FIG. 41.—Raised sea-terraces of the Alten Fjord, Norway.

gen is fringed with raised beaches up to a 147 feet. The coast-line of northern Russia ria for hundreds of miles has been recently out of the sea, as is shown by the raised beaches hells. It would appear, indeed (see Lesson XXVI. 21) that the tundras and steppes, e Arctic Ocean to the Sea of Aral ck Sea, are only an upraised

[illegible] [illegible]

[illegible] the sea most
[illegible] and south-
[illegible] the Mediter-
[illegible] the great
[illegible] there
[illegible] use of
[illegible]

[illegible] the
[illegible] ap-
[illegible] shown
[illegible] seaport
[illegible] their
[illegible] now
[illegible] roots
[illegible] be
[illegible] different
[illegible] south-west of

[illegible] subsidence
[illegible] by the
[illegible] These
[illegible] limestone,
[illegible] Some-
[illegible] instance of
[illegible] upon
[illegible] and
[illegible] height in
[illegible]
[illegible] These are
[illegible] Africa
[illegible] shores
[illegible] shows a
[illegible] by a

[illegible] It

ɛirt a continent, as in the north east of Australia, the great reef fronts the land for 1,000 miles ; or it ncircle an island, as at Tahiti. It rises from such water outside that its slope to the sea must be very . Inside it is separated from the land by a deep

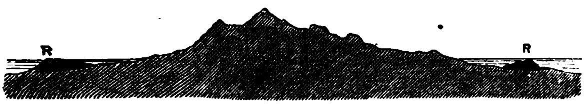


FIG. 42.—Section of an island (L) with a Fringing coral reef (R).

oon channel. This structure is shown in Fig. 43. ere may sometimes be more than one island inside barrier reef.

21. The third form of reef has received the name of toll or coral island. It is a ring of coral rising out of e middle of a deep ocean, and having a breadth of bout a quarter of a mile. The water outside is so proɔund close to the island that the outer slope of the reef lown to the bottom of the ocean must be a submarine

IG. 43.—Seetion of an island (L) with a Barrier reef (R).

e. Inside lies a lagoon of comparatively shallow
e delicate branching kinds of coral.
l is represented in Fig. 44, and
45. No land exists inside. The
ts from the outer edge of the re

[illegible] there
[illegible] their
[illegible] more

out twenty fathoms from the surface. The only e to be drawn is that the bottom has been ly sinking, while the little coral-builders have kept th the subsidence and maintained their reef at the el.

The three sections just given (Figs. 42, 43, and 44) ate the stages in this subsidence. First we have the g reef, with its shallow lagoon and not very deep outside. Then this shore reef passes into the er reef, with its deeper lagoon channel and much r sea outside. The land inside becomes less in t and extent as it settles down beneath the sea-level. st it sinks out of sight altogether, and the barrier remains as an atoll.

many instances, however, it would appear that the l began to grow round the edges of tall volcanic peaks g out of mid-ocean. In such cases it may not be essary to suppose subsidence of the bottom. For the ct of the waves in cutting away the edges of the coral ght combine with the growth of the coral itself to keep outer margin of the reef tolerably steep, and even to ow out from the land upon a slope of coral debris.[1]

From the evidence furnished by coral reefs it has inferred that vast tracts of the sea-floor are sinking. en Madagascar and the southern parts of Hindostan Indian Ocean presents a series of atolls, some of e the Chagos Bank, are actually submerged. al Pacific Ocean a still more extensive series m the Caroline Islands to the further end Archipelago—a distance of fully one hundred itude.

[1] from their recent observations by the edition, as I am informed by Mr. John

LESSON XXIV.—THE WATERS OF THE LAND.

Springs and Underground Rivers.

1. In Lesson X. we traced some of the characters of a vast circulation of water between air, sea, and land. We found that from every water-surface on the globe invisible vapour is ascending into the air, where it is condensed into clouds, and whence it is returned to the surface of the earth again in rain, dew, snow, hail, or sleet.

2. The more we reflect upon the part which water plays in the general plan of our planet, the more importance shall we assign to it. The clouds form and melt and form again. Day by day, or season by season, the rain-showers reappear to moisten the parched soil. The brook and waterfall are ever rushing downwards, and yet they are continually fed with renewed supplies from above. The river still bears its broad breast of waters to the sea, as it has done ever since the earliest tribes of men settled upon its banks. The sea, though receiving the surplus drainage of all the continents, is not thereby raised in level, but yields to the air those abundant vapours which are borne back to the land, and, there condensed into running water, once more renew the downward journey to the sea. This continual coming and going of water may be looked upon as the pulsation of the very life-blood of our globe as a habitable planet.

3. Let it be remembered, too, that water enters largely into the composition of the bodies both of plants and animals. If its circulation were arrested our earth would cease to be the green populous planet which it is at present. Clouds, springs, rivers would disappear. Scorched by the fierce heat of the sun during the day,

frozen by the intense cold of radiation at night, the
l would become lifeless and silent.

. As was shown in Lesson X., the moisture of the returns to the land either in the liquid form, as water, in the solid form, as ice. We have now to follow 'urther progress over the land under each of these con-ons. In the liquid state the moisture chiefly appears Rain; in the solid state as Snow.

. When rain reaches the surface of the land, part of it cs into the soil and the rest flows off into brooks and rs, by which it is carried back to the sea. It is con-ient to follow first the course of that portion of the rain ch disappears underground. At first sight we might urally suppose that it is permanently absorbed into the th. But if it were withdrawn from the surface-circula-ı its abstraction would evidently tell upon the amount water flowing over the land. Rivers and lakes would ink in size or dry up altogether. Yet we do not find ; to be the case. There must be some way in which water that sinks into the ground is restored to the face again. This takes place by means of **springs**, ich are the outflow of the subterranean water from nings in the ground.

. The intimate connection between ordinary springs l the rainfall is familiar to every one. We know that in eason of drought many springs and wells give a limited ply of water, or fail altogether, while as wet weather s in they fill again. It is clear that they derive their plies from rain-water which has percolated through rocks beneath the surface. Such springs as have a p-seated origin are less affected, or do not sensibly fer at all from surface-changes, because they gather ir stores from a wider area of subterranean drainage, ere the effects of a scarcity of rain take longer to make mselves felt than is the case near the surface.

ɛs, even the hardest, are porous, and therefore
ʼater ; the channels of brooks and rivers, the
s, and the floor of the sea are all more or
so as to present openings for the descent of
rain-water, therefore, does not remain in the
:s lower still and finds its way through the
ints of the rocks which lie below. Water is
plied by lakes, rivers, and the sea, either
gh the mass of the rock underneath, or avail-
he open cracks, and pouring downwards into
ıg with it sand and other impurities.

ing deep wells in some districts of France,
her parts of plants have come up with the
water from a depth of nearly 400 feet.
ic remains were comparatively fresh, and
l to have travelled in underground channels
ɔ miles distant, and to have been three or
ɔn their subterranean journey. The same
ıas been observed in other places ; some-
fish have been brought up in borings from
feet.

result of this constant percolation and
ɜr from the surface, the rocks for some way
ny places charged with moisture. Proofs
ɔnstant presence of water are furnished in
nd mines, in short, in nearly every place
siderable cutting is made through rock.
ground water which forms one of the
ɜs in quarrying and mining operations.
duction of steam machinery many coal-
been worked to a certain depth, had to
ɔm the impossibility of getting rid of the
re then said in the expressive language
be "drowned." The powerful pumping
everywhere in the coal-fields

t to the abundance of the water below ground, to the labour and cost which are necessary for oving it.

o. Another and familiar illustration of the way in ch water everywhere pervades the soil and rocks is to seen in the sinking of wells. In most parts of the rld these artificial cavities are dug out to serve as :eptacles wherein the water which is soaking through e rocks may be collected. Wells may be successlly made even in places where it could hardly be sup›sed that water would be found. Thus on the borders f the African deserts, where little or no rain falls, nd where therefore there can be but a scant supply f water from the surface, serviceable wells are dug. The French colonists of Algeria sink what are known as 'Artesian wells" (Art. 18) on the northern margin of the great desert of Sahara, and the sandy tracts between Cairo and Suez yield water even so near the surface as at a depth of fifty feet. The existence of those fertile green patches called Oases in the midst of the barren deserts of Africa and Arabia is due to the rise of springs. Again in the valley of the Mahanadi and other Indian rivers, where in the dry season little or no rain falls, a hole dug out to the depth of thirty or forty feet is sure even then to be partly filled with water.

Hence the springs of a district do not always or necessarily obtain their water from the rainfall of the immediate neighbourhood. If that were the case there could hardly be perennial springs and wells in the African deserts, where rain is exceedingly rare.

11. To what depth the water will descend must depend greatly upon the nature and condition of the rocks at each locality. Very deep mines are often without water. When the Alps were pierced in making the railway tunnel between France and Italy, the rocks at a depth of more than 5,000

feet below the summit of Mont Cenis were quite dry. We need not suppose, therefore, that the water generally sinks to a very great depth. But here and there it no doubt does find its way down even into the intensely hot regions whence lava-streams proceed. It is this subterranean water which, as we saw in Lesson XXII., issues abundantly in vast clouds of steam, and plays so important a part in the arrangements of active volcanoes. It is probable that in spite of the plentiful discharge of steam at these volcanic openings, a part of the water which descends so far may be permanently lost, by being decomposed, and forced to enter into chemical combination with parts of the melted rocks. If this be the case, then the earth must be losing a little of its water; slowly and insensibly, indeed, but yet if continuously, with the probable result of ultimately reducing our planet to the dry and sterile condition of the moon.

12. Though the water which falls upon the land is distributed over the surface as rain, it does not reappear at the surface oozing everywhere from the soil. Sinking underground it finds its way along cracks and hollows of the rocks below, until it comes out again to the surface at certain points. Rain-water, though it falls over a whole district, at once runs off into brooks and larger streams, until it finally enters the sea. Somewhat in the same way the underground drainage is collected from many branching channels and brought out to the surface in springs.

13. A difficulty may sometimes be felt in understanding how the water having once sunk down can ever be driven up again. But we must remember that the springs which form its points of escape at the surface lie at a lower level than the ground from which the original supplies of rain have been drawn. If we try to realize to ourselves the manner in which the underground circulation is effected we see that it must be in one or other of two ways:

er by simple gravitation, as in what may be called face Springs, or by hydrostatic pressure, as in Deepted Springs.

ι4. (I.) In the case of Surface Springs the water ich has been steadily flowing downward as well as ward in its underground course comes to a point iere, owing to some depression of the land, it finds ;elf again at the surface. The subjoined woodcut will :plain how such springs arise. A porous bed of rock ·), or one traversed with cracks or joints, lies nearest the ırface, and allows the rain-water to soak through it down o a stiff impervious layer (*a*) by which the descent of the vater is arrested. Unable therefore to sink further down-

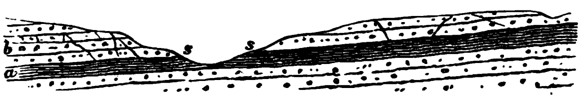


FIG. 46.—Section across a valley to show how the simplest kinds of springs arise.

ward, the water flows along the surface of this lower bed. If a valley should happen to cut through these rocks, there will be a spring or line of springs (*s*) on the junction of the two rocks along the side of the valley. In the same way the rain which falls upon a mountain may sink underground and gush out in springs at the foot of the mountain. In springs of this kind the water merely descends in the ordinary way by gravitation, and issues where the surface happens to sink below the level of the subterranean water-channel. In heavy rain a good deal of water soaks through the soil into the nearest brooks without ever forming actual springs.

15. Wherever water accumulates among underground rocks, whether in the pores or in the open crevic

so as to convert the rocks into subterranean reservoirs, it will rise in them up to the lowest levels at which it can find outlets to the surface, where it will appear in these surface- or land-springs. This water level must be reached before a well can catch a supply of water.

16. (II.) In Deep-seated springs, on the other hand, the water has in its journey sunk to a lower level than its point of escape, and has risen again by hydrostatic pressure, as in a syphon. Evidently the arms of a syphon may be as long as we choose to make them, yet while the one is longer than the other, and is supplied with water at the top, the water will continue to flow out from the top of the shorter arm. In like manner the subterranean

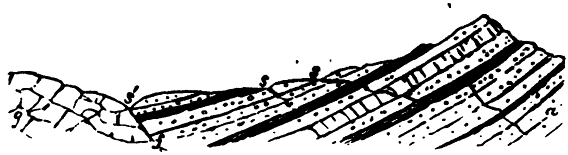


FIG. 47.—Section to show how deep-seated springs arise.

channel of a deep-seated spring may descend for hundreds of feet, yet the water which fills it will not cease to flow and to rise again to the surface. Having reached its greatest depth, often far below the level of the sea, the water accumulates there, saturating such porous rocks as lie in its way, until the pressure of the column of water behind it forces it up any fissure which may allow of its escape to the surface, and there it bubbles up as a spring. As in the accompanying figure (Fig. 47), the rain which falls on the high grounds, and is absorbed by the rocks and soil, flows down more or less permeable rocks which are arranged in different beds or *strata* (*a*). Taking advantage of the cracks which may opportunely present

...lves, as much of the [illegible]
...t rises through [illegible]
...trata are broken [illegible]
which brings them against [illegible]
...a considerable body [illegible]
. Hence the [illegible]
...s is often traceable [illegible]
...ngs.

7. In nature the course which water [illegible]

FIG. 48.—Section to show the intricate under[illegible] drainage which [illegible] in a deep-seated spring. The [illegible] and [illegible] lead the water at last into a main channel, by which [illegible] surface as a spring at s.

ground is in reality for the most part much more com-plicated than is shown in this diagram. All rocks are ...undantly traversed by divisional planes, called "joints;" ... likewise full of cracks, and they present many ...ges in texture. So that the water finds a most intri... ...etwork of passages through which it must make its ... It may many times come near to the surface and

th filters through the sands and gravels (*b*) at the top the chalk (*a*), and is imprisoned by the retentive ndon clay (*c*).[1] When the wells are sunk down to this ter-bearing zone, the water ascends in abundance. So ny wells, however, have now been made that the level the water in them has gradually sunk year by year, the nsumption being thus somewhat more rapid than the pply to the underground reservoirs.

19. In trying to picture to ourselves the amount of ater which is always circulating under ground, we ought ot to measure it merely by what is seen coming out at he surface in well-marked springs. For in the first place ve must bear in mind that the abundance of springs is eally much greater than might at first sight appear. Much of the water which rises from under ground does not bubble up in the form of well-marked springs. When it reaches the surface it soaks through the soil or trickles over it in tiny runnels. On cultivated land such places are marked by greener patches of vegetation, or by tufts of rushes and a swampy soil. Sometimes, too, we may see them exposed even on ploughed fields during dry weather in spring time. From want of rain the bare soil gets dried and light in colour, but here and there it is diversified with dark brown patches. These point to places where the water is oozing out from below and soaking through the soil in spite of the drain-pipes of the farmer. In these and similar cases the water after coming up to the surface, sinks down again into the rocks and commences another underground journey.

20. In the second place we must remember that the natural flow of water from a higher to a lower level must carry much of the underground drainage to the rocks under the sea, so that when the water rises to the surface

[1] In the diagram the curve of the beds has necessarily been greatly exaggerated, there being in reality hardly a basin at all.

lved in the water, and do not interfere with its clear- and brilliancy, nor in most cases do they impart to it taste. They may be found in the water of every ıg, but their quantity varies greatly. Sometimes they ır in such minute proportions as fifty parts in every ion parts of water; in other cases they rise to as much 32,700 parts in the million, which is about the same the proportion of salts in some parts of the Pacific ean. (See Art. 30.)

23. Three questions naturally arise in reference to this narkable impregnation of all spring-water: firstly, what e the substances present in the water? Secondly, how es the water obtain them? and, thirdly, what is the sult of their constant removal by the water?

24. (i.) Substances contained in spring-water. f you take a glass of bright sparkling spring-water and et it stand for a time, you may observe minute bubbles adhering to the inner surface of the glass. These are air, or gas, which has been dissolved in the water. They rise by degrees and escape, and when they have done so the water ceases to have the same fresh brisk taste which it had when first drawn from the spring. In like manner, if the water is boiled it acquires an unpleasant insipid taste, not because anything has been put into it, but because the air or gas which it contained has been driven out. Hence it appears that at least one cause of the pleasantness of spring-water to the taste is the presence of gaseous materials.

25. Chemists have carefully examined these materials, and ha[illegible]d that they consist of oxygen, nitrogen, and carbo[illegible] t is, the ordinary gases of the air, some- times [illegible] dition of sulphuretted hydrogen, which [illegible]g taste to the waters in which it occurs. [illegible] the proportion of dissolved gas is so [illegible]rdly recognisable, even in a chemical

[illegible]

[illegible] mineral matter [illegible] affects [illegible] flows over the [illegible]. The [illegible] and this. [illegible] away [illegible] stones. [illegible] When the [illegible] little more [illegible] the plant lies [illegible] the outward form of [illegible] springs, as they are [illegible] and [illegible] centri-

, occur abundantly in limestone countries. In other ;s, iron is the principal substance contained in the , which has in consequence a strong inky taste. It happens that as the water flows along, it deposits ɔn as a yellow scum on the sides of its channel. ;s of this nature are known as *ferruginous* or *chaly-*

Common salt is the characteristic of some springs, hen they contain a large proportion of it they re- the name of *brine*-springs. Sometimes they are or quite saturated with salt, that is, they could ıld any more in solution. Many springs containing siderable admixture of mineral ingredients are use- certain diseases, either in the form of draughts or hs. They are termed *Medicinal* springs. For ex- , the waters of Bath contain carbonate of lime, .te of soda, sulphate of lime, chloride of sodium, and carbonic acid ; those of Harrogate, carbonates gnesia and lime, sulphate of magnesia, chlorides of ı, magnesium, and lime, nitrogen, carbonic acid ulphuretted hydrogen. The waters of Vichy are ıe and acidulous from the quantity of soda, and carbonic acid which they contain. Those ·lsbad abound in sulphates, those of Wiesbaden in les.

n mountainous and snow-covered ground, spring- be met with scarcely above the freezing-point. extreme, every degree of temperature may be ifferent springs up to such boiling fountains as rs. Evidently, the temperature of the spring end u of the rocks from which the es. r comes from melting snow be cold. If it sinks deep come within the influence of warm. So that there seems temperature as affording some

the water
to which the water

most
warm or
with
wells are warm.
temperature of
also in France,
One of
in hot water is
already alluded to as
springs, and as being
round the orifices
is in the Geysers of
and New Zealand Lesson

held in solution,
common spring-
100 parts in every
districts where the water
2,000 parts in every
the proportion is of course
waters, the solid
contain $\frac{16408}{1000000}$;
The proportion in
about, while in the

of water as well as the pro-
matter is large, we see that
out of the rocks below
springs must be enormous.
in Switzerland,
estimated to bring
tons of pounds
be all collected

it would form a square column, upwards of 650 feet high, and twenty-seven feet on each side. The brine spring of Neusalzwerk, near Minden, has been found to yield in one year enough of brine to form a cube of solid salt, measuring seventy-two feet. The wells of Bath, in like manner, are computed to yield annually enough of mineral matter to form a square pillar ten feet in the side, and eighty feet high.

32. (ii.) Origin of the Substances dissolved in Spring-water. We saw in Lesson VI. how rain in its descent takes up a little air together with some of the gases or other substances present in the air. One of these is carbonic acid. More of the same acid is obtained when the descending water reaches decomposing plant and animal remains in the soil. In some parts of the world, as in such old volcanic districts as Auvergne, in Central France, and the Eifel, in Rhenish Prussia, carbonic acid is given off in great quantities from subterranean sources, and is here and there brought up by springs, which like the Bad Tönnistein in the valley of Brohl, are so full of it that it escapes in copious bubbles when the water comes to the surface.

33. It is important to notice the sources whence underground water obtains its carbonic acid, because the presence of this acid gives the water great power in dissolving many mineral substances. How this solution takes place may be admirably illustrated above ground, by what happens at the arches of many bridges. If you stand beneath an arch, or the vaulted roof of a cellar, you may often observe that each line of mortar between the courses of masonry is marked by a sort of fringe of slender white stalks or pencils which hang downward. A little further observation will show you that at the point of each of these pendent stalks, a clear drop of water is hanging, which in time falls to the ground, and is slowly

[illegible] beneath
[illegible] you will find
[illegible] white deposit
[illegible] mounds,
[illegible] of the
[illegible] appeared
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[illegible] that they
[illegible] water
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[illegible] acid, has
[illegible] solution in
[illegible] The
[illegible] consists of
[illegible] or brick,
[illegible] which falls
[illegible] joints of
[illegible] upper to
[illegible] lime,
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ı on the roof. They carry a good deal of it with
ı when they fall to the ground. There they evaporate
further, and consequently deposit more lime as a white
l crust called *stalagmite*. This process of removal
re-deposit, seen so well in a small way in arches of
onry, occurs sometimes on a magnificent scale, in vast
stone caverns, as will be referred to further on in this
son.

16. If now in sinking through a few feet of masonry,
ı-water can work such great changes, what may we not
ect to take place beneath the ground where the water
s to traverse vast masses of rock, and may have its
portion of gases, including carbonic acid, increased
it moves along! We should remember, too, how
eatly augmented the solvent power of water must
come, down in the hot interior, as is shown by the
equent large admixture of mineral ingredients in the
ater of thermal springs. There need be no wonder
erefore that every spring contains more or less of these
ngredients.

37. (iii.) **Results of the removal of materials rom below in spring-water.** Let us now consider
what must be the consequence of this universal percolation
of water through the underground rocks, and of the
removal and transport to the surface of so much of their
solid substance. Evidently there are two points of view
...h this question may be looked at: in the first,
n the surface, in the second, the effects below

alise in some degree the influence which the
stances brought up by springs have upon what
the surface, we may reflect that the springs
thus, indirectly, the sea, with
ıble ingredients. In fresh-
ı, there are large tribes of

[illegible]

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of the Julian Alps. It is a tableland of limestone, so full of holes as to resemble a sponge. All the rain which falls upon it is at once swallowed up and disappears in underground channels, where as it rushes among the rocks it can be heard even from the surface. Some of the holes which open upon the surface lead downward for several hundred feet. Some turn aside and pass into tunnels in which the collected waters move along as large and rapid subterranean rivers, either gushing out like the Timao at the outer edge of the tableland, or actually passing for some distance beyond the shore, and finding an outlet below the sea. Here and there the labyrinths of the honeycombed rocks expand into a vast chamber with stalactites of snowy crystalline lime hanging from the roof or connecting it by massive pillars and partitions with the floor. Such is the famous grotto of Adelsburg near Trieste—a series of caverns and passages with a river rushing across them.

41. Still more extensive is the Mammoth Cave of Kentucky—a cavern about ten miles long, but with many ramifying passages which are said to have a united length of more than 200 miles. In the island of Antiparos a famous grotto lies 600 feet below ground, forming a spacious hall 300 feet wide and 240 feet high.

42. Partly from the solvent action of the descending water upon [illegible] rides of the chinks of the limestone, and
[illegible]rtly from [illegible]g in of the roofs of the underground
[illegible]sages, [illegible] of the ground in some limestone
[illegible]ntries [illegible] holes, and at the same time is so
[illegible]re of a [illegible] becomes a kind of barren and dry
[illegible]sert, [illegible] its springs and its rivers are with-
drawn [illegible]rfa[illegible] In the course of time the
ground [illegible] [illegible]sided to such an extent as
to [illegible] [illegible]vater collects into lakes.
Th[illegible] [illegible] the surface. The water

issues from openings in the rocks to fill them and flows away by other openings of the same kind. The Zirknitz See in Carniola is a good instance of a lake of this kind. It is about five miles long and from one to two miles broad, but usually not more than from six to ten feet deep. Its bottom is said to be perforated with about 400 funnels or pipes through which the water ascends. In wet weather it rises to three times its ordinary height. But even at high water, it is so surrounded with high ground, that it cannot find any outlet at the surface and has to discharge its surplus waters down some of the innumerable caverns in the limestone (see Lesson XXVI., Art. 13).

43. From what has been said it appears that in some parts of the world (notably where limestone occurs largely) the surface of the ground is greatly changed by the chemical action of subterranean water. There is yet another way in which the circulation of water below ground affects the form of the surface. Where rain sinks through a porous sloping bed of soil or rock it sometimes forms a loose, watery layer underneath, which, by destroying the support of the overlying mass, allows the latter to slip down the slope and tumble into fragments below. This is called a landslip. Changes of this kind can of course only occur on the side of mountains, cliffs, ravines, or steep slopes generally, where movement by gravity from a higher to a lower level is possible. They are common along the sea-coast, many parts of the shore-line of the British islands being fringed with old landslips. When the slipped mass is large in extent and becomes covered with vegetation, it forms a strip of broken and picturesque ground in front of the higher cliff behind. Such is the undercliff of the Isle of Wight, and the long line of rough crags and grassy mounds flanking the steep cliffs of Antrim. In the latter case (Fig. 50) a great tableland of ancient hard lava beds (*b*)

rises from the coast in a line of noble cliffs resting upon layers of much softer and more porous rocks (*s*). Owing to the loosening of the support of the upper part of the cliff by the trickling of water between the beds in the

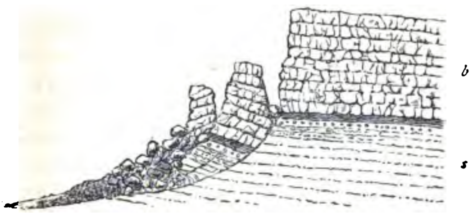
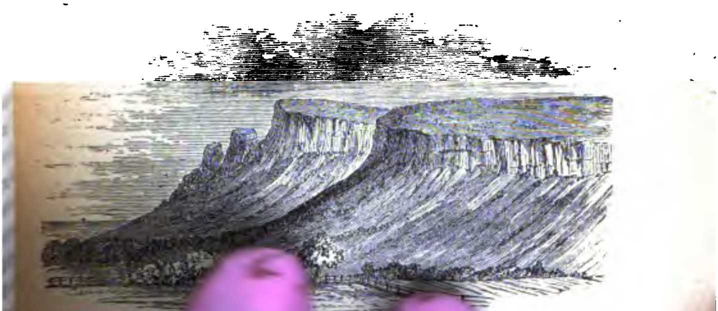


FIG. 50.—Section across the cliff and landslip of Antrim.

lower half, huge slices of the heavy solid lava-rocks have been launched down to the low ground. Many of these fallen fragments are themselves large enough to be called hills.



51.– [illegible] the cliff [illegible] Antrim.

h[illegible] subje[illegible] ins landslips
q[illegible] e. T[illegible] pper layers of
[illegible] ter, [illegible] nd slide down

the slopes, carrying trees and fields to the valleys below, and piling up vast heaps of ruin there. In Sikkim, and other districts to the south of the Himalayan chain, the surface of the ground is being altered from this cause after every heavy fall of rain, vast spaces of mountain-slope many acres in extent being detached so as to sweep down, with their covering of forest, into the lower ground. Sometimes these fallen masses of earth and rock are thrown across a valley, so as to bar back the river and form a lake. But as the barrier consists only of loose rubbish, it is apt to give way to the pressure of the accumulating waters, which then pour down the valley with great force, sweeping everything before them, and desolating the district for many miles along their course.

45. When landslips take place in well-peopled and cultivated valleys they sometimes cause great destruction of life and property. Thus, in the valley of Goldau, Switzerland, in the year 1806, after a continuance of wet weather, a bed of rock, 100 feet thick, resting on saturated sandy layers, slipped down. The whole side of the mountain of the Rossberg seemed to be in motion. In a few minutes the descending mass had, with a terrible noise, rushed across the valley, burying five villages and about 500 people under a mass of ruined rocks 100 to 250 feet high.

LESSON XXV.—THE WATERS OF THE LAND.

Running water.—Brooks and Rivers.

1. Having in the last lesson followed the course of that portion of the rainfall which disappears into the ground, we have now to trace what becomes of the rest. Since

the surface of the land is higher than the sea, and s[...] downward to the sea-level, the water which falls u[...] from the sky cannot remain there but must in obe[...] to gravity seek the lowest level. This it can only [...] moving downward till it flows into the sea. We[...] land inclined from a central ridge with even slop[...] the roof of a house, we can suppose that the rain [...] run off in sheets of water. But instead of such uni[...] it everywhere presents the most irregular surface. [...] on what we might suppose to be a perfectly le[...] smooth piece of ground, there are innumerab[...] heights and hollows, which become at once [...] during a shower of rain, for then the hollows are [...] by tiny runnels of water which course along th[...] lower level.

2. Water-courses and River-basins.—Owing to the unevenness of the surface of the land th[...] rain runs off into the hollows, down which it flo[...] can descend no further. These hollows or chan[...] receive and conduct the drainage of the land [...] water-courses or streams. They vary in [...] the merest rill or gutter up to the broad river w[...] the drainage of half a continent to the sea.

[...] of any large country or o[...] [...]gement of the water[...] [...]hey are grouped some[...] In the low gro[...] [...] of a tree. [...] one single trunk, bends to [...] further inland it divides into [...] smaller branches, and so [...] drained by the [...] the drainag[...] [...]ittle runnels i[...] [...] more as th[...] few main str[...]

4. Let us in imagination trace the course of a large river from its beginning in the midst of a continent, to its end in the sea. Among the far mountains, where the sources of the river must be sought, the higher summits are covered, or at least streaked, with snow, while long tongues of snow and ice may often be seen creeping down the upper parts of the valleys. Perhaps the river issues from the melting end of a "glacier" (see Lesson XXVIII.). If so, it springs up at once as a tumultuous torrent of muddy water, and rushes down the valley receiving from either side innumerable minor torrents and runnels, which descend the rugged slopes, either from the melting edge of the snow, or from abundant clear bubbling springs. Or the river takes its origin in some single spring, not larger perhaps than many others in its neighbourhood, but which has been fixed upon from early times by the human population of the district as the true fountain of the river. Such a spring, either welling quietly from the ground or gushing out copiously, supplies the first little stream which dashes down its rocky channel, receiving from each side, as it descends, many tributary torrents, until after leaping from rock to rock in foaming cascades, and working its way through deep gullies, it reaches the more level part of the valley. In this first or torrent-part of its course the infant river is only one of many such streams by which the sides of the higher mountains are channelled.

5. But when it gains the valley it enters on a second and distinct portion of its journey. Its flow is less rapid, its channel less steep and uneven. It winds to and fro in many bends and loops across the flat parts of the valley, and rushes through the narrow gorges which occur at intervals. It still grows, by the addition of many smaller streams from either side, and becomes more and more like a true river as it rolls along. This valley part is by far

the longest and most important in its course. Here it receives most of its water, and puts on its distinguishing characters as a river. Its tributaries are no longer mere torrents or brooks, but rivers, sometimes as large as itself. But as these increase in size they become fewer in number, so that in the last stages of its journey, the main stream receives few or no affluents.

6. When at last, quitting the valley which has conducted it through the hills and the lower undulating country, the

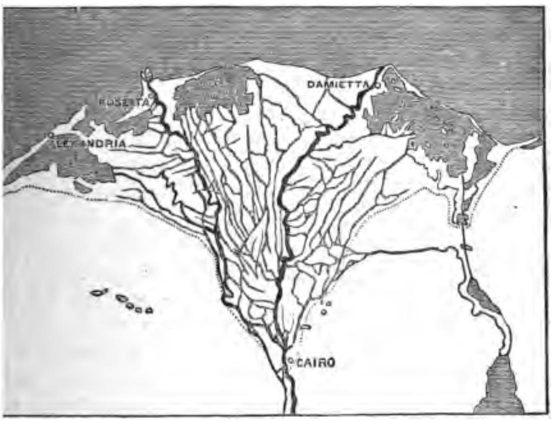


FIG. 52 —Delta of the Nile.

reaches the low plains, towards the sea, it enters the last section of its course, that of the delta. rto it has always been receiving but never giving off hes. But now, reaching the low level land of the it begins to divide, sending off many arms which :o and fro, and again divide among the swampy flats. ıch may the river ramify in this part of its course, may enter the sea by many channels, or mouths.

often so nearly of the same size that it may be hard to say which of them should be called the chief. Moreover, these intricate channels are constantly shifting their position as the river-water moves seaward. Hence what was once the chief mouth is now perhaps half-filled up, and the principal discharge takes place by another channel at some distance on the edge of the delta.

7. It will be noticed on a map, that except where flowing along some straight valley among mountains, most rivers do not run in a straight line for more than a very short distance. This is the case in every part of their course. The channel is continually winding from side to side. On a small scale you may observe the same arrangement of curving water-lines when the rain during a heavy shower is running down a sloping piece of roadway. At the upper part the runnels, though always rushing downwards, cannot, owing to the unevenness of the ground, descend in straight lines, but are deflected, now to one side, now to another, by little pebbles or bits of clay or other roughnesses on the road. Where straight ruts have been made for them by cart wheels they take advantage of these, and flow then in straight courses, as a river does in a longitudinal valley. But they escape before long, and resume their winding way as before, joining each other in the descent, and swelling the main runnel which sweeps down the road and eventually finds its way into some neighbouring ditch. What the pebbles, ruts, and other roughnesses on the road are to the rain, the uneven surface of the country is to the brooks and rivers. In either case the water seeks the readiest path of escape to lower levels. But this path is seldom the shortest. Every obstacle which the water cannot surmount or remove, serves to turn it aside, and, as such obstacles abound, the flow of the water is a continuous series of turnings and windings. Ridges and hollows, heights and valleys, turn

the streams, now to one side, now to another, until the waters find at last a rest in the great sea. Fig. 53 represents the serpentine curves of part of the course of the Missisippi.

8. Amidst these bendings it will sometimes happen

53.—Windings of the Mississippi. The shaded part marks the alluvial plain.

he river eventually cuts through the narrow part of
rtens and straightens its channel.
hut off from the river by the accu-
nud, and becomes a crescent-shaped
gnant water. Instances of this kind

occur commonly along the courses of streams which flow through flat land, as in the case of the Mississippi (Fig. 55). In the delta of the Rhone they are called "Aigues Mortes."

9. One consequence of the frequent shifting of the direction of a river-course is that it becomes impossible to speak of the east or west side, or the north or south bank of a river. Obviously what is at one place the east side, may be successively the north, south, and west sides in the space of a few miles. Accordingly, it is usual to call one side the right bank, and the other the left bank, the observer being supposed to be looking down the river in the direction of its flow.

10. Another feature which a map makes clear is that each large river is the natural drain for a wide region. For instance, all the surplus rain and the discharge from melted snow and springs from by far the largest part of North America, find an outlet to the sea by a single river—the Mississippi. The space drained by this river is computed to be 1,244,000 square miles. This is termed the drainage-basin or catchment-basin of the river. The drainage-basin of the Ganges is estimated at 432,480 square miles; that of the Rhine at 75,000; that of the Thames at 5,162, of the Shannon at 4,590, and of the Tay at 2,090 square miles.

11. If you take a map of North America and trace a pencil line round the sources of all the streams which are tributary to the Mississippi, that line will represent what is called the water-shed[1] or water-parting. To the north of it you will find the basins of the Mackenzie,

[1] Sir John Herschel proposed to write this word *water-sched*, meaning "separation of the waters, not water-*shed*, the slope *down which* the waters run" (*Physical Geography*, p. 120). But the original meaning of "shed" was to divide, or part, and this use of the word still holds in Scotland, where a girl is said to *shed* her hair in the middle. The idea of disjunction is a secondary one, which has gradually come to be the common usage of the word.

and of the rivers which drain into Hudson's Bay, to the east the St. Lawrence and the smaller rivers of the Eastern States, while to the west the Fraser, Columbia, Sacramento, Colorado, and many lesser rivers carry the drainage of the Rocky Mountain slopes into the Pacific Ocean.

12. The water-shed of a country or continent is thus a line which divides the flow of the brooks and rivers on two opposite slopes. On many maps you will find it marked as if it were a ridge or mountain-chain. But in reality it does not necessarily coincide with the highest ground. Trace on the map of Europe, for example, a encil line between the streams which drain to the Atlantic, laltic, and North Sea on the one side, and those which rain to the Mediterranean, Black, and Caspian Seas on le other; you will thereby mark the general water-shed the continent. You will find that the line, instead of nning along and coinciding with any central mountain-ain, crosses all the great mountains, table-lands, and ins. Beginning at Gibraltar, it traverses the table-land of Spanish Peninsula, crosses obliquely the chain of the enees, passes athwart the plateau of Central France the right bank of the Rhone, runs through and across ranges of the Alps, the Black Forest, and the Car-ians, and then descends into the vast plains of sia, across which it winds in a general north-easterly the chain of the Urals. That the water-shed be a high ridge, may often be noticed even on ntly undulating ground, where the same valley e a stream at either end flowing in opposite s. the water-shed being a quite imperceptible rise n them.

om a map some important lessons itry by noting the line of its water-m runs down the centre of a region

like the ridge on the roof of a house. Very commonly it lies much to one side, and winds in great curves as it traverses the land. Now the position of the water-shed, like the axis described in Lesson XIX., Art. 25, suffices to indicate the relative slopes of the two sides of a continent or country, especially where these two sides descend to the sea-level. Take South America by way of illustration. The water-shed of the whole continent lies near the western coast-line. The slope facing the Pacific must thus be very much steeper than that which looks towards the Atlantic. A heavy shower of rain falling on the water-shed will of course run off partly to the west and partly to the east. The westward portion, starting from a height of perhaps 10,000 feet, will reach the Pacific after a journey of not more than seventy miles in direct distance; while the other half, setting out from the same elevation, will have a journey of about 2,000 miles in a straight line before it can enter the Atlantic. The water-shed of Hindostan, south of the Gulf of Cambay, is another example of this one-sided position. On a smaller scale, Scandinavia, Great Britain, and Spain illustrate the same feature.

14. When a water-shed runs close to one edge of a continent, there is no room for large rivers on that side; these must flow on the opposite slope. America again furnishes an admirable instance of this obvious arrangement. In South America, for example, there is no river of large size flowing down the short slope into the Pacific, but on the east side the largest rivers of the world bear the drainage into the Atlantic.

15. Sources of Rivers.—Every shower of rain which falls, and every spring which rises, within the drainage basin of a river, may be regarded as one of the sources of the river. In many parts of the world indeed, such, for example, as the central and southern regions of India,

where there are dry and rainy seasons, and where the rivers do not take their rise in high snowy mountainous ground, the water which floods the streams during the wet months is mostly derived from the rain which runs off the saturated soil. In common language, however, the source of a river is understood to mean the point from which the head-waters of the main branch of the river take their rise. It is often hard to say which of the branches of a large river should be called the chief. One may be largest in volume of water, another greatest in length of course. One of the branches has usually been selected by the people of the country, and called by them the main stream.

16. Large rivers rise from various sources—springs, rains, melted snows or the ends of glaciers (see Lesson XXVIII.), and lakes. A great proportion of them may be traced up till their furthest little tributary brook is found gushing out as a spring from the side of some hill or mountain. In limestone countries, as we found in the foregoing Lesson, large rivers sometimes issue from the caverns by which the underground rocks are there perforated. Occasional or periodical rain directly supplies much of the water of many rivers. The Nile, for example, owes its annual rise to the heavy rainfall of the wet season among the mountains of Abyssinia. The snow-fields of the higher mountains furnish unfailing nourishment to many of the largest rivers of the globe. Thus in Europe, the Rhine and the Rhone take their rise from the melted snow and ice of the Alps. In Asia the rivers of No-thern India descend from the melting snows

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...f the giant chain of the Himalaya. In
...a the abundant patches of snow which
...her parts of the Rocky Mountains supply
...vater which drains from the west into the
...f the Mississippi. Here and there among

the higher summits of the land little hollows arrest the first runnels of melted snow or of springs, and form little lakes, out of which the infant waters of important rivers flow. Or a lake, formed on lower ground by the confluence of several tributaries, fills a vast hollow of the land, whence the united drainage escapes by one large river, like the Rhine from the Lake of Constance.

17. Proportion of the Rain-fall carried to sea by Rivers.—Since the size of rivers depends upon the amount of rain-fall or snow-fall within their drainage-basins, we may naturally inquire how much of the total moisture discharged from the air upon the land is actually returned to the sea by the rivers. The proportion between rain-fall and river-discharge has never been very satisfactorily determined, but is said to vary from $\frac{1}{3}$ to $\frac{1}{4}$; that is to say, only about a third or a fourth part of the water which falls upon the land as rain or snow is carried off by the streams. The greater portion is returned to the air again by evaporation. From the moistened soil, from every surface of snow or water, from each spring, brook, lake, and river, vapour is continually passing into the air. The rivers, therefore, do not bear to the sea even all the water poured into them, for they are continually losing water by evaporation from their surface.

18. The diminution of rivers, the drying up of brooks, and the cessation of springs during seasons of drought, show how dependent is the flow of water over the land upon its circulation through the air. In countries such as Britain, where heavy rains may occur at any time of the year, the rivers are subject to irregular increase. In those regions, however, where a wet and dry season succeed each other at certain intervals, the rivers have their periodical rise and fall. The most familiar example of this regularity is that shown by the historical river—the Nile. Egypt, through which this river flows in

the lower part of its course, is a singularly dry country. Rain seldom falls there, and yet every year, and with such regularity that almost the very day of the change may be foretold, the river begins to rise, and continues to do so until the low plains on either side are overflowed. It then slowly subsides, leaving a film of fine mud over the ground, and resumes its former channel. This remarkable feature puzzled the ancients very much. They accounted for it by supposing that the Nile rose among snowy mountains far to the south, and that the inundations were caused by the melting of the snows. But in recent years the true cause has been ascertained. The high and rocky table-land of Abyssinia is visited by heavy rains during the months of March and April. The numerous gullies and gorges which intersect that rugged country, and which were previously quite dry, are then filled with torrents of water, which rush down and swell that branch of the great river known as the Blue Nile. It is these annual rains in the far highlands of Abyssinia, therefore, which cause the regular inundation of the rainless plains of Egypt.

19. In countries liable to heavy periodical rains, the [illegible] ween the flow of the rivers and the rain-fall is [illegible] ngly clear [illegible] stance [illegible] Mahanadi River in Central [illegible] sin within the area to which [illegible] gs the copious rains alluded [illegible] upon high rocky ground, the [illegible] by innumerable channels to [illegible], unable to find in its channel [illegible] flows the surrounding country, [illegible] rse. But in the dry [illegible] river is low, for then [illegible] ls for its water upon [illegible] rings.

[illegible] elation between the

rain-fall and rivers is supplied by those singular dry ravines and gravel-tracks so common in Syria, Arabia, and the Valley of the Euphrates, called "wadys." Those within tracts which have a rainy season are turned into water-courses during the wet part of the year. But over a great part of the region where they occur, little or no rain falls, so that they remain constantly dry. That they were once the channels of brooks and rivers cannot be doubted. It is apparent that a change has taken place in the climate of these districts, partly caused or at least aggravated by the destruction of the ancient woods and forests, and the abandonment of the cultivation of the soil. The rains which once refreshed the land have ceased to fall, the river-beds which carried the surplus water to the sea are now dry, and the valleys are parched and barren.

21. In a country which is subject, like Britain, to heavy rains at different and uncertain times of the year, the rivers are liable to be swollen on any day; and as heavy rain often succeeds dry weather, the rivers may pass rapidly from a state of low water to full flood. Where, as in the case of the Nile, the rain comes regularly at the same season, the river swells and falls again with remarkable slowness and uniformity. But there is another cause of the regular, as well as irregular, flooding of rivers. It is evident that where a river draws its supplies of water in great part from the melting of snow among the mountains, it will have a larger volume in summer and autumn than in winter and spring. The Rhine and Rhone, for example, which take their rise among the snows and glaciers of the Alps, fill their channels with water during the dry hot weather of July and August, and shrink in size during the cold and often wet months of the year. Besides this annual increase and diminution, these rivers are liable to occasional and sometimes disastrous floods in summer, not caused by heavy rains, but by dry and warm

weather. When the warm south wind called *Föhn* blows upon the snowy slopes of the Alps, it causes a rapid thaw. Torrents of milky snow-water dart down the sides of the mountains and feed the brooks, these soon swell and rush forward into the rivers, which rapidly rise and sweep down their valleys, often carrying away bridges, inundating meadows and strewing them over with gravel, or even breaking down the houses in the lower parts of villages and towns built upon their banks.

22. Flow of Rivers.—Standing by the bank of a broad rushing river, we ask ourselves sometimes at what rate the water is moving, and how much passes before us in an hour or day. In most cases we shall probably guess the rate of motion to be faster than it is, for the broad stream, with its eddies and gurglings of water, impresses us with the idea of rapidity as well as of volume. The rate of flow is determined by the angle of slope and the volume of water. Measuring the average angle of slope down which rivers flow, we learn that it is considerably less than we might have expected it to be. The average declivity of the larger rivers of the continents probably does not exceed two feet in the mile. The Missouri has a mean fall of 28 inches in the mile; but the Volga does not slope more than 3 inches in the mile. To be easily navigable, a river should not have a mean declivity of more than 10 inches in the mile or 1 in 6336. Of course, in their mountain-track, streams have much higher angles of descent. That of the Arve at Chamounix is 1 in 616, and that of the Durance varies from 1 in 467 to 1 in 208. But such rapid declivities give rise to the motion of torrents rather than of rivers.

23. A moderate rate of the flow of a river is about 1¼ mile in the hour; that of a rapid torrent does not exceed 18 or 20 miles in the hour. The larger rivers of Britain have a velocity varying from about 1 mile to about

3 miles in the hour. Hence we may walk by the margin of a river and easily outstrip the rate of its current.

24. But the water of a river does not flow in every part of the channel at the same rate. Owing to friction against its bed, the river moves slower at the sides and bottom than in the middle. On a small stream you can easily prove this by throwing in pieces of wood and watching how much faster those travel which fall in the middle than those which have lighted near the edge. Evidently, therefore, the addition of more water to the same channel will increase the rate of motion of the stream. When two rivers join into one their united streams may occupy a channel no broader than one of them did before, but even without acquiring any increased slope in its bed, it runs faster, because the water has now the friction of only one channel instead of two. For the same reason, a river confined in a deep narrow gorge runs faster than where, with a like declivity, it spreads over a broad gravelly bed. When this cause is kept in mind we can understand the meaning of the curious fact that a river is sometimes not increased in breadth even by the influx of large tributaries. Thus the Mississippi becomes no wider even after it receives its largest affluents. Eighteen hundred miles above its mouth it is 5,000 feet, or nearly a mile, broad. But at New Orleans, where it enters the Gulf after having been successively fed by the vast streams of the Missouri, Ohio, Arkansas, and Red Rivers, it is only 2,470 feet broad, or less than half a mile, and yet in that comparatively narrow channel the drainage of nearly half a continent passes out to the sea.

25. Volume of Water discharged by Rivers.—Measurements and estimates have been made of the amount of water carried annually into the sea, or hourly past certain places by different rivers. The Mississippi, for example, has been found, after a careful survey of its operations, to

discharge annually into the Gulf of Mexico no less than 21,300,000,000,000 cubic feet of water, enough to make a lake as large as the whole of England and Wales and twelve feet deep. The Danube sends into the Black Sea 207,000 cubic feet of water every second. The Tay, though not the largest river in the British Islands, brings down more water into the sea than any other, its annual discharge being estimated at 144,020,000,000 cubic feet.

LESSON XXVI.—THE WATERS OF THE LAND.

Lakes and Inland Seas.

1. OWING to the inequalities on the surface of the land, the water which falls upon it cannot always flow off at once into the sea. Hollows occur which intercept the drainage until it fills them and flows over from the lowest parts of their margins, or otherwise escapes. Such water-filled basins are called lakes, but when they are of large size and are occupied by salt water, they receive the name of inland seas.

Lakes.

2. At first we might expect to meet with lakes indifferently on any part of the earth's surface. Any good general map of the world, however, shows that they are not distributed altogether at random, but are chiefly developed in certain regions. By considering this development we can better understand how the hollows came to exist at all, and why they should be where we now find them.

3. (1) First, then, in the northern hemisphere an extraordinary abundance of lakes may be observed to be scattered over the northern parts of Europe down to about the 52nd parallel of latitude, and in America to about the 42nd parallel. In some districts within these regions there

seems to be almost as much water as land. In Finland, for example, nearly a third of the country is covered with lakes and marshes, and as there are no mountain-ridges, and no dominant lines of valley, the undulating surface looks like that of a land which has been half submerged.

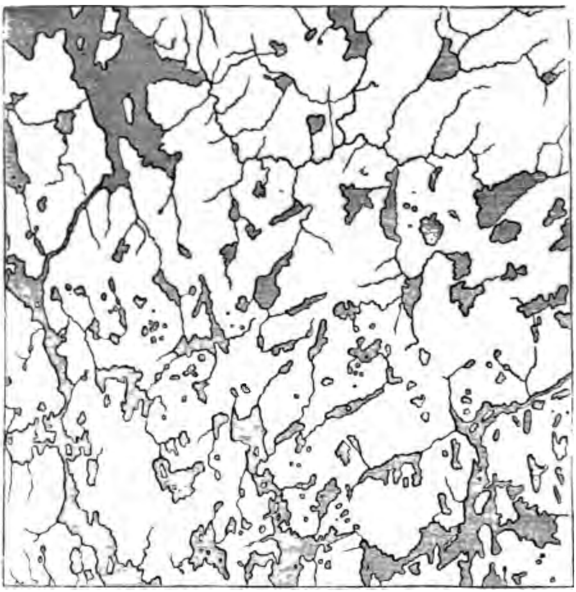

FIG. 54.—Part of the Island of Lewis, illustrating the abundant lakes of the north-west of Europe.

In the north-west of Scotland similar scenery occurs ; from some of the hill-tops there the undulating surface of the low country is seen to be plentifully strewn with lakes. In the accompanying figure (Fig. 54) a representation on the

scale of one inch to a mile is given of a portion of the surface of Lewis, one of the islands of the Outer Hebrides, from which some idea may be formed of the abundance and irregular distribution of these sheets of water. Again in North America, the British possessions and a large part of the north-eastern States are plentifully dotted over with lakes, varying in size from such vast basins as that of Lake Superior down to mere pools or tarns.

4. In these regions, the lakes not being confined to the valleys, but lying indiscriminately over the surface, may be found at any height from the sea-level to near the crest of the land. The ground is generally undulating rather than

Fig. 55.—*Section of a lake-basin excavated in solid rock.*

hilly, and seldom rises more than a few hundred feet above the sea. The abundance of lakes in the northern portions of the northern hemisphere has been associated by many geologists with the fact that these regions have been covered with sheets of ice which, grinding down the surface of the land, have left it strewn with clay, gravel, and sand. How ice performs this kind of work is described in Lesson XXVIII. Many of the lakes lie in hollows excavated out of the solid rock (Fig. 55), which still retains abundantly the scratches and groovings made upon it by the movement of the ice. Other sheets of water are inclosed the heaps of debris left on the land when the ice (Fig. 56).

5. (2) On further examination of the map it will be noticed that lakes occur more or less abundantly among mountains. Take Europe as an illustration. Even in the comparatively low mountain groups of Scotland, Cumberland, and Wales, lakes abound and form one of the great charms of the well-known scenery of these

FIG. 56.—Section of a lake-basin lying in a hollow of superficial detritus.

districts. Among the Alps a series of large lakes occurs on each side of the main axis of the chain, and innumerable minor sheets of water occur scattered at all heights among the central mountains, up even to the borders of the snow-line. All mountain systems have not the same

FIG. 57.—Section of a lake dammed up by a barrier of earth or gravel.

abundance of water-filled hollows ; in some, indeed, few or none occur. Lakes of this class may be hollows formed during the elevation of the mountains (see Lesson XXIX); or, like those referred to in Art. 4, may either have had their basins scooped out by glaciers or formed by the irregular piling up of ice-borne debris, as shown in Fig. 57.

In most volcanic districts lakes occur filling cavities which have been formerly blown open by explosions from below.

6. (3) A third series of lakes may be observed to occupy depressions on the table-lands. The most remarkable examples are furnished by the great lakes of Equatorial Africa. Of these the Victoria Nyanza lies at a height of about 3,300 feet above the sea, and is believed to cover an area of not less than 30,000 square miles. On the same continent a vast depression, with many small lakes, extends westward from the Nile valley, and stretches between the southern limits of Barbary and the country drained by the River Niger. Another smaller hollow lies in the southern part of the continent, and contains some small lakes, of which Lake Ngami (2,900 feet above the sea) is the largest. On the great table-land of Asia numerous lakes occur over Thibet, Turkestan, and Mongolia.

7. It will be noticed that many of these table-land lakes have no outlet. They lie in hollows below the general level of the surrounding country, and while they receive supplies of water from the streams which drain into them, no river escapes even from the lowest parts of their borders. Now most of them are filled with salt water. The reason of this is found in the fact, which has already been considered in Lesson XXIV., that water flowing over or through rocks dissolves out of them some of their soluble ingredients. Among the substances so removed, common salt, sulphate and carbonate of lime, and sulphate of magnesia are of common occurrence. These dissolved salts are carried down by rivers, and in most cases find their way ultimately into the sea. But in the depressions of the great table-lands the water flows into hollows from which it cannot escape except by evaporation. These lakes may be compared to great evaporating vats or

troughs, like those in which sea-water is boiled down in the manufacture of salt. The water passes off into invisible vapour, but leaves its various dissolved mineral substances behind. Hence year by year these lakes and pools become salter. When they dry up they leave a crust of salt upon the ground which they once covered. The soil is in such places so impregnated with salt, that plants will not grow upon it, and its arid sandy surface stretches for leagues as an inhospitable desert.

8. Where a fresh-water lake does occur in these regions it will be found to have some outlet by which its surplus water is removed, so as to prevent increase of saltness. Lake Chad in Central Africa lies in a hollow from which no river escapes to the sea, and it was believed in consequence that this fresh-water lake had no outflow, and was thus an exception to the general rule. More recently, however, a river has been found opening from its north-eastern margin and carrying the overflow along a wide valley, in which the water is finally dried up amid sandy wastes.

9. In the eastern countries bordering the Mediterranean many salt-lakes occur as well as ground incrusted or impregnated with salt. The naturally-formed salt has been used from time immemorial by the dwellers there. A little reflection on the mode of its formation and its composition explains the meaning of a curious passage in the Bible which is not in itself very intelligible. It occurs in the Sermon on the Mount. "If the salt have lost his savour, wherewith shall it be salted? it is thenceforth good for nothing, but to be cast out, and to be trodden under foot of men." (St. Matthew, v. 13.) Were the substance here spoken of our common salt (chloride of sodium), it would be difficult to explain how it could possibly lose its taste without ceasing to exist at all. Its taste is to us as essential a character

as its chemical constitution. But no doubt the substance referred to was the white incrustation obtained from the sides of the salt lakes and the bottoms of the dried-up saline pools. Now this incrustation, besides common salt, contains also magnesia, lime, and other ingredients. In short it resembles what may be obtained by the evaporation of sea-water. Of these various components common salt, as was shown in Lesson XIII. Art. 5, is the most soluble. It is the last to appear when the water is evaporated, and the first to disappear when moisture is supplied again. We can see therefore that the white natural crust used by the people of Syria for salt, being kept for a time and exposed to damp or rain, might lose all its salt. The more insoluble residue, consisting of gypsum, carbonate of lime, &c., though in appearance unchanged, yet having little or no taste, would be quite useless for the purposes for which the salt had been gathered. The question, therefore, might well be asked—"If the salt have lost his savour (or saltness), wherewith shall it be salted?"

10. (4) A fourth series of lakes occurs along many parts of the margin of the land where the ground is low and consists of soft sandy, clayey, or gravelly materials. These maritime sheets of water are known by the name of **lagoons**. In Europe they fringe all the Prussian shores of the Baltic, reappear on the west of Denmark, Holland, and Belgium, and are found at intervals along the northern coasts of the Mediterranean Sea, from the east of Spain to the western shores of Greece. In Asia they extend for hundreds of miles along the eastern and western sides of the peninsula of Hindostan. In America a long line of them skirts the Atlantic sea-board of the United States.

11. Lagoons along the sea-margin are for the most part shallow and narrow, running parallel with the coast, from which they are separated by a strip of low land formed

of sand, gravel, or other loose materials. When the sea flows into them the waters are salt or brackish. When they only communicate with the sea by a narrow outlet, or when they have no outflow, but soak through the porous bar which banks them out from the sea, they are fresh.

12. Most lakes derive their water from streams which flow into them. In Fig. 54, for example, this connection is well shown, though there the feeders of the smaller lakes are too minute to be shown upon the map. Many valleys contain chains of lakes along their course. A river flowing in one of these valleys appears alternately to contract and expand, having a comparatively rapid flow where it takes its own river-form, and losing itself in still water when it enters a lake. It would seem that this arrangement was formerly commoner than now, for the rivers have frequently filled up their lakes, and now wind to and fro across flat meadows where the lakes once stood.

13. But lakes likewise derive their supplies partly from springs which rise beneath them. In some cases, indeed, the whole supply comes from such underground sources. The Lake Zirknitz near Trieste (Lesson XXIV. Art. 42), affords an excellent illustration of this feature. It comes and goes with the seasons. After long drought it disappears, but when heavy rains fall on the surrounding mountains of Carniola, which are formed of remarkably honeycombed limestones, the water sinks out of sight, and after filling the underground passages, comes out with a roaring noise from the funnels and caverns which open upward into the hollow of Zirknitz. This hollow is then converted into a lake. No stream flows out of it, since both its supply and its overflow pass away by underground channels. This example shows how lakes, like rivers, depend ultimately upon the rain-fall for their water, and are apt to vary in level with the wetness or dryness of the seasons. In Northern Africa also, the

Sebka-el-Faroon, a hollow 100 miles in length, lying to the south of Tunis, at a level of several feet below the Mediterranean, is in winter covered with water to the depth of two or three feet. Having no outlet, and undergoing rapid evaporation during the parching summer of that hot climate, the lake disappears and leaves a salt-crusted floor.

14. Some of the largest fresh-water lakes in the world are those of North America, Lake Superior alone covering an area of 23,000 square miles, its surface being 627 feet above the level of the Atlantic, and its average depth nearly 1,000 feet. Another series of vast sheets of fresh-water lies in the eastern part of the table-land of equatorial Africa, and forms the source whence the Nile and the Congo take their rise. In the heart of Asia, Lake Baikal stands at a height of 1,363 feet above the sea, and covers a space 370 miles in length, by from 20 to 70 in breadth. On these vast sheets of water storms arise on a scale hardly inferior to that of the sea itself. Fresh-water, being lighter, is more easily stirred by the wind than salt-water. It is soon raised into ripples, and when deep and wide, and driven onward under the pressure of a continuous high gale, it rises into large waves, which roll across and burst in foam against the windward shore, heaping up gravel and sand, or cutting [illegible] the cliffs, as is elsewhere done by the waves [illegible] Lesson XVIII. Art. 11).

15. The depth [illegible] almo[illegible] as wide [illegible]d indefinite [illegible] ize. [illegible] the land [illegible] a lake [illegible] an in[illegible] probable [illegible] of the [illegible] if the [illegible] and slopes [illegible] into [illegible] may [illegible] confidence [illegible] the la[illegible] hallow [illegible] other hand the [illegible] und [illegible] of [illegible] when a lake fills [illegible] valle[illegible] preci[illegible] n-ridge[illegible] we may be pr[illegible] that [illegible] S[illegible] of the

950 feet, marked 41°·7. Similar observations on the other deep lakes of Switzerland and Northern Italy show that they all have a permanent mass of cold water at the bottom. Yet the mean annual temperature of the surface water of the Lake of Geneva as it issues into the Rhone is nearly 4° warmer than that of the air. Further south the Lago Sabatino, near Rome, was found to have a temperature of 77° at the surface, but one of 44° at a depth of 490 feet. Lakes, like the sea, exercise an important equalizing influence on temperature, preventing the air around them from being so much heated in summer and so much cooled in winter as would otherwise happen. (Lesson XXXI., Art. 20.)

18. One great and useful office of lakes is to regulate the flow of the rivers which issue from them. They receive the water discharged by heavy rains and rapidly-melted snows, spread it over a large surface, and allow it gradually to escape by the outflowing river. In this way they prevent the occurrence of those sudden and destructive floods, which, in the absence of such natural reservoirs, are apt to occur in all countries subject to copious rain, or where large masses of snow may be quickly thawed. Another part played by lakes is that of arresting the gravel, sand, and mud brought down by the streams which flow into them. These materials, which so often discolour the tributary brooks and rivers, fall to the bottom when the currents are checked by entering the still lake-water. The lakes in this way filter the rivers. The Rhone, for instance, is a muddy stream where it enters the Lake of Geneva, but at the lower end, where it quits the lake, its water is as pure and limpid as that of a spring. Its sediment has been dropped upon the bottom of the lake, which must consequently be slowly rising. The Lake of Geneva is being gradually filled up in the manner already referred to in Art. 12.

Inland Seas.

20. From what has been said in a previous part of this Lesson, it is not difficult to trace upon a map those areas of the earth's surface where the lakes are filled with salt-water. In every tract of land into which rivers flow without any outlet, and where the water must pass off by evaporation, we may expect to find brackish or salt lakes. A salt lake, therefore, need not necessarily have been once connected with the main ocean. So constantly are salts present in fresh-water, that any fresh-water lake where the only escape for the water is by evaporation, will eventually become salt. The salt lakes on the table-lands of Asia and Africa were, no doubt, fresh at first, and have gradually grown salt as the process of evaporation has been continued century after century. In North America, too, the Great Salt Lake in Utah, lying at a height of 4,200 feet above the sea, and covering a space of 75 miles in length, by from 15 to 40 in breadth, together with many other smaller salt lakes in the same region, show the same effect.

21. But in some parts of the world there exist sheets of salt-water which can be shown to have been once connected with the main body of the ocean, from which they have been separated by subterranean movements. Such Inland seas may have their surface below the level of the sea, or they may have been carried up together with the land around them, so as to lie at a higher level than the surface of the main ocean. By far the most remarkable of these is the chain of inland seas and smaller sheets of salt-water which extend from the Black Sea and Sea of Azov, eastward by the basin of the Caspian and Aral Sea, and thence northward through the vast steppes and mossy barren plains, or "tundras"—a low region

hich has been elevated, at a comparatively recent time, ut of the sea. The Arctic Ocean, as already stated Lessons XII., Art. 21, and XXIII., Art. 17), is believed at ne time to have run southward as a broad sea up to the ountains of Persia, a distance of more than 3,000 miles. wing to some of those underground movements already escribed, that ancient mediterranean arm of the sea hich separated Europe and Asia has been raised into nd. But in the deeper cavities of the depression porons of the sea still remain, retaining even yet the marine ells, fishes, and seals which abounded in the water fore the elevation of its bed. Of these relics the largest d most important is the Caspian Sea, which lies 84 feet low the level of the Black Sea, is from 2,000 to 3,000 t deep in the central parts, and covers an area of about ,000 square miles. It receives the drainage of the ole of the south-east of Russia in Europe by such imrtant rivers as the Volga and the Ural, but it has no let. So large is the mass of fresh-water poured into Caspian, that the saltness of the greater part of that is not more than about one-third that of ordinary -water (Lesson XIII., Art. 6). But along the shore nerous lagoons occur, where, in the dry and hot weather summer, so much evaporation goes on that the water omes intensely bitter and salt, and saline incrustations m at the bottom and on the shores. On the east side the sea lies the wide but shallow Karaboghas Bay, may be looked upon as a vast evaporating basin. nt is always passing in through the narrow opening, e is said to be no compensating under-current out- so that, as the water-level does not rise, all this inflow must be supplying the loss by evaporation. therefore, grows every year salter. A s ms on the bottom of some of the shall res, and the water is there so sali

cord on being let down into it and pulled up again is immediately crusted over with salt. Seals, which used to flourish there, are said to have been driven away by the increasing saltness of the water.

22. The Sea of Aral fills another of the hollows lying in the vast depression between the European and Asiatic high-grounds. It is a lake of brackish water 265 miles long and 145 broad. It is said to be at a height of only 33 feet above the level of the sea. On its southern side it receives the Oxus, which carries into it the drainage from the northern slopes of the great chain of the Hindu Kush mountains. It likewise obtains supplies of water and mud from the Jaxartes, which takes its rise among the lofty Thian-Shan mountains. Yet the Sea of Aral, like the Caspian, has no river flowing out of it. It loses by evaporation as much water as it receives. Indeed the loss from this cause would seem at present to be greater than the supply of water, for the sea is said to be sensibly decreasing in size.

23. Still further north smaller salt-lakes are scattered over the plain. That these are likewise parts of the vanished sea which once filled all that broad and long tract, seems to be put beyond doubt by the fact that they still contain shells and other kinds of marine life. Traces of dead shells are likewise met with all over the plains, and it has been observed that among these the characteristically Arctic species become more numerous towards the north.

24. The valley of the Dead Sea is remarkable as being the most depressed on any part of the land of the globe. The surface of that sheet of water is 1,298 feet below the level of the Mediterranean Sea. The water, so intensely salt as to be a kind of brine, contains in every 100 parts rather more than 24 parts by weight of salts, or about eight times the proportion in ordinary sea-water.

LESSON XXVII.—THE WATERS OF THE LAND.

The Work of Running Water.

1. In the two previous Lessons we have followed the circulation of running water over the surface of the land. That surface we have found to be traversed by an elaborate network of branching water-courses, which, stretching from the slopes of the central mountains down to the sea-shore, carry back to the ocean the surplus drainage of the land. We have seen how in the hollows of the land the water gathers into lakes, yet that it does not accumulate indefinitely there, since it either overflows and again takes the form of streams, or passes off by evaporation. Delivered to the sea, and mingling once more with that great body of water, it is anew raised by the sun's heat into invisible vapour, and carried by winds across the land to begin again the same circulation.

2. So vast a body of water ceaselessly moving over the land cannot but modify the forms of the mountains, hills, valleys, and plains on which it falls and flows. We shall now consider what the nature of such change may be, and how it is effected, beginning with the tiny rain-drop, and tracing the operations of running water down to the mouths of the great rivers as they enter the sea.

3. **Rain.**—The action of rain in washing the air was described in Lesson X., Art. 35. Its further influence in decomposing rocks underneath the surface of the ground was traced in Lesson XXIV. The same kind of change takes place upon the surface of the land. Rain-water, by means of the acids which it takes out of the air, or absorbs from decomposing vegetable matter when it

reaches the land, attacks rocks exposed to the air, dissolving and removing the more soluble parts of them, thereby loosening their cohesion and causing them gradually to crumble down. Calcareous rocks like marble, suffer much from this kind of waste; but even hard rocks like granite, do not escape. In so far as it depends on the solvent action of the acids upon some of the ingredients of the stone, the process is distinctly a chemical one. But when the outer layer or crust of the rock has in this manner been loosened, heavy rain may wash off the disintegrated particles, and thereby expose a new surface to further decay. The action now becomes mechanical. These two combined kinds of change powerfully influence the scenery of the land (Lesson XXIX.).

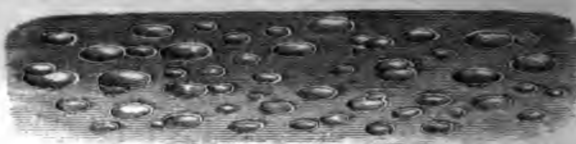

FIG. 58.—Prints made in soft mud or moist sand by rain-drops.

4. The little prints which the rain-drops leave upon a surface of moist clay or sand offer the simplest instance of the mechanical action of rain. From such apparently trivial effects many stages may be traced, until we reach huge pillars, like those shown in Fig. 59, which have been carved out by the blows of innumerable rain-drops. The material of these columns is a stiff earth or clay, stuck full of stones and large blocks of rock, and readily crumbling down under the influence of the weather. The large blocks, remaining of course unwasted, serve each to protect the portion of the earth lying underneath it, while the surrounding clay is washed down. Thus the block

becomes, as it were, the capital of a pillar which seems to rise slowly out of the rest of the earthy mass. Each pillar stands as a monument of the waste which is going

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show the extent of material which has been removed. In such cases, following the rain after it has beaten upon the earth and coursed down the declivities, we find that on reaching the more level ground it has spread out some of the particles which it had washed off, and formed a layer or deposit of them there.

5. Here then may be seen in the action of the rain-drops a sort of type of that of all the great rivers of the globe. It is threefold. First we have Erosion, in the loosening of the particles of earth or rock. Secondly, Transport, in the removal of these loosened particles, and the consequent exposure of fresh surfaces to waste; and thirdly, Deposit, in the laying down of a new stratum formed out of the removed materials. Let us now see how these three kinds of action are manifested over the surface of the land by rivers.

6. **Erosion.**—Every runnel, brook, and river, in short every current of water, no matter how small, which moves over the land is busy removing part of the soil or rock over which it flows. This work, like that of the rain-drops (Art. 3), is twofold. In the first place, the rain and the water of the streams dissolve certain parts of the solid substance of the land and carry them away in chemical solution. In countries where the rocks consist of limestone, or contain a large proportion of the more readily soluble substances, a very considerable amount of waste is carried on by this means, although the water is not visibly affected in colour or transparency. Some idea of the extent of the loss thus sustained by the surface of the land may be formed from the amount of dissolved mineral matter which is found in the water of rivers (Art. 14).

7. In the second place, the solvent action of rain and the disintegrating effects of frost (Lesson XXVII.) cause the surface of exposed rocks to crumble down. Loose clay

and sand are thereby produced, and the hardest rocks are split into fragments. This debris of the land, washed away by the rain and brooks, becomes the instrument of still further destruction. As it is hurried along, its particles, ground against each other, are reduced still further in size, and at the same time are worn smooth and round. They thus acquire that familiar water-worn character which we recognise as the most obvious and distinguishing feature of the detritus in the channel of a stream. So constant is this character, that when, at any point in the course of a river, sharp-edged fragments appear on the banks, we naturally conclude that they cannot have lain very long in the current, nor have travelled very far. The fragments, the longer they are rolled about, and the further they are carried, grow smaller in size, until at the far end of the river they may be found as mere fine sand and mud. If you set out to trace this fine sediment to its source, you would have to seek it among the rocks of the far distant mountains, in the higher part of the river-basin. And you might be able to trace it step by step until you found the huge blocks loosened from the parent cliffs, which in the course of ages have supplied a constant and abundant tribute of detritus to the river. In some respects a river may be compared to an enormous grinding-mill, where large pieces of stone go in at one end, and only fine sand and mud are seen to emerge at the other.

8. But the loose materials swept away by the streams not only wear each other down, they likewise erode the sides and bottom of the water-courses. The water-worn character is thus not confined to the loose sand, gravel, and stones, but is as marked upon the solid rocks over which these materials are driven. Even the hardest kinds of stone cannot resist constant friction. They become smooth and polished, though where out of the reach of the water they may have a rough surface and sharp edges.

Sometimes the upper limit of the grinding action of the flooded stream is in this way well defined along the sides of a rocky ravine.

9. In the course of time the stream grinds out a channel for itself through even the hardest rocks. This channel, however, is seldom a mere deep straight trench. The rocks offering many varying degrees of resistance to erosion, they are worn down unequally, being scooped

FIG. 60.—View of ravines cut by streams out of a table-land.

out where more easily worn away, and projecting where more durable. The stream, thrown from side to side, dashes along, sweeping onward the sand and mud which it drives over its rocky bed, and excavating those winding picturesque ravines which are familiar features in the water-courses of all countries.

10. Along the walls of these ravines when the water is low, curious round cauldron-shaped cavities with smooth

sides may often be observed. These are known as *p*
holes (Fig. 61), and are formed, as may be observed wh
the water is in flood, by the grinding action of loc
stones, which, caught in eddies of the water, are kept

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...so as ... the hole
...es ... sand
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[illegible] numerous [illegible]
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[illegible] channel
[illegible] always

[illegible]

[illegible] waterfall may [illegible] or steep [illegible] have deter- [illegible] waterfall can be [illegible] stream, carving out [illegible] commencement and [illegible] This excavation is [illegible] whereby the [illegible] loosened. So long

as these crumble down more easily than those at the top of the fall, the cliff over which the water dashes will remain precipitous. Slice after slice being cut off its face, it will shift its place further and further up the stream. The fall will still continue to pour over its edge, and, though slowly moving up the gorge, will preserve from year to year the same general appearance. If, however, from any difference in the nature or position of the rocks, the rate of waste should become more rapid at the top of the cliff than at the bottom, the cliff, instead of overhanging, will then begin to retire at its upper part. As this goes on the waterfall will gradually grow less marked, until it passes into the condition of rapids, that is, a shoot of water over a steep and rough part of the bed. Finally, these rapids will themselves be worn down, and all trace of the original fall will disappear, except the gorge which it excavated during its recession.

12. Almost every large river flowing through a hilly or mountainous region illustrates these features of the erosive action of running water. Perhaps the most stupendous example is that of the Niagara River. The famous Falls of Niagara consist of two vast cascades separated by a small island, and having a united breadth of 950 yards and a height of 140 to 160 feet. It has been computed that 670,[illegible]00 tons of water are poured every minute over these falls into the foaming torrent below, from which vast clouds of spray [illegible] up into the air. Originally the falls [illegible] at [illegible] where the limestone forms a cliff [illegible] Since that period, however, the [illegible] ceded for about seven miles to its [illegible] it it is still moving upwards is shown [illegible] the lar[illegible] rock which from time to time fall [illegible] om the [illegible] ich [illegible] water rushes. The rate of retreat h[illegible] out one foot in the year. Probabl[illegible] estimate; if it be taken

as an average for the past work of the river, somewhere about 35,000 years must have been required to excavate the ravine between the present Niagara Falls and Queenstown.

13. Every stream, then, which drives along sand and gravel on its bottom is busy with the work of erosion. Even in ordinary weather this action may be perceived; how much more stupendous must it be in floods, when ever little runnel is swollen, when earth, sand, and stones are swept by rain off the ground, and when the rivers, rising high above their ordinary level, and acquiring from the increase of their volume augmented velocity of flow, rush over the land and bear their vast burden of detritus down to the sea.

14. Transport.—The loose materials acquired in the process of erosion must be removed and disposed of by the streams. As long as the water has velocity enough it keeps the sediment moving, and conveys it sometimes to vast distances. Any check to the velocity causes some of the sediment to fall to the bottom. In considering the nature and amount of work done by rivers in the transport of mineral materials on the land we must bear in mind that these materials exist not only in visible form, such as sand and mud, but invisibly dissolved in the water. So that we should carry away an incomplete notion of the work unless we took this latter part of it into account. We have traced how every spring is busily employed in bringing up to the surface the mineral substances which the water has dissolved out of the underground rocks, and how rain and the water of streams are similarly engaged above ground. Now this dissolved material is conveyed by runnels, brooks, and rivers into the sea. It is not difficult to make a probable estimate of the amount of invisible mineral substance thus carried by a river. First the amount of water discharged by the

river must be ascertained, then the average proportion of mineral ingredients contained in a gallon or other given quantity of the water. The one sum multiplied by the other will of course give us the required result. The celebrated chemist Bischoff calculated that the Rhine carries past Bonn every year enough carbonate of lime chemically dissolved in its water to form three hundred and thirty-two thousand millions of oysters of the usual size, and that if all these oysters could be put together they would form a cube measuring 560 feet in the side. The river Rhone is estimated to carry past Avignon every year 8,290,464 tons of dissolved salts in its water.

15. But by far the largest amount of mineral matter borne by rivers from the land is in the form of mechanical sediment—gravel, sand, and mud. Every river is more or less muddy. After heavy rain even the clearest brook has its water discoloured by the earth it is carrying down. The mere discoloration therefore is a proof of the constant transport of sediment by running water. The amount of material thus transported depends partly, of course, upon the carrying power of the river, which is regulated by its volume and velocity, partly upon the nature of the soil and rocks of its drainage-basin, whether they happen to be earthy and easily worn away or the reverse, partly upon the distribution of the rain-fall, whether it is spread r all the seasons of the year, or crowded into a few :s or months, so as to produce swollen and muddy 's while it lasts, and partly, where the river takes its from a glacier, upon the quantity of mud which .pes from the melting end of the ice. (See Lesson VIII

ing a current of about half a mile in comparatively feeble flow, can carry ay soil suspended in the water. With inches in a second, which is about

two-thirds of a mile in the hour, it can roll along fine gravel, while, when the rate rises to three feet in a second, or a little more than two miles in the hour, it can sweep away slippery angular stones as large as an egg. We can readily understand that in torrents, where the velocity rises so high, as was stated in Lesson XXV., Art. 22, the power of transport must be enormous. Huge masses of rock as large as a house have been known to be moved during heavy floods.

17. It is evident, therefore, that in a rapid river or brook, the mud which discolours its water represents only a part of the sediment which it is carrying down. A great deal of sand and gravel, or even coarse shingle, is at the same time being pushed along the bottom. We may even hear the stones rattling against each other as they are rolled onward by the current.

18. Measurements and estimates have been made of the proportion of sediment in the water of different rivers. This proportion varies of course in different seasons, being greatest during floods and least when the rivers are low. The Ganges during its four months of flood is stated to contain one part of sediment in every 428 parts by weight of water, while the mean average for the year is one part in 510. In the water of the Irrawaddy the proportion was found to be one part in 1,700 by weight of water during floods, and one part in 5,725 during the dry season. In the water of the Mississippi the average proportion was determined to be one part in 1,500 by weight, or one part in every 2,900 by volume of water. The Danube has been found to contain a mean proportion of $\frac{1}{3080}$ by weight of suspended matter, and during extraordinary floods discharges into the Black Sea as much as 2,500,000 tons of silt in twenty-four hours.

19. But in any estimate of the total discharge, the coarse, heavy sediment which is pushed along the bottom

must also be allowed for. In the case of the Mississippi this moving layer has been estimated to deliver into the Gulf of Mexico the vast amount of 750,000,000 cubic feet of earth, sand, and gravel every year.

20. Having ascertained the average quantity of mineral matter suspended in the water or pushed along the bottom, and having estimated the average amount of water carried by a river into the sea, we easily obtain by mere multiplication the total quantity of sediment removed from the land by that river in a year. Thus the Rhone is estimated to carry into the Mediterranean every year rather more than six hundred millions of cubic feet of sediment. The discharge of the Danube into the Black Sea has been determined to be 67,760,000 tons of silt annually. The mean yearly amount of solid matter carried in suspension by the Mississippi into the Gulf of Mexico is estimated about 362,723,000 tons; and this, including the coarse at sand and gravel which are pushed along the bottom, would make a column one mile square and 268 feet high. We may form some notion of this amount of material by supposing that 1,100 merchantmen, each laden with 1,000 tons of it, were to arrive every day for a whole year at the mouth of the Mississippi and discharge their cargoes into the sea, ... would only equal as carriers the work of this ...

... ny rivers greatly exceed the Mississippi in ... of solid matter which they transport. ... rainy season in India the streams become ... ud. ... ingstone in his African travels ... an ... rents of sand moving along ... amount of water. In trying ... ads of particles of sand and ... against his legs, even in dry ... after the rains the quantity of ... treams must be enormous.

22. The amount of sediment carried down by a river to the sea in a year represents the extent of loss which the region drained by the river has sustained within that time. Knowing the quantity of sediment and the area of country from which it has been derived, we can determine the amount by which the general surface of the river-basin has been lowered. Thus at its present rate of work the Mississippi reduces the general level of its drainage area $\frac{1}{6000}$ of a foot annually, or one foot in 6,000 years. Could this rate of denudation be continually kept up over the surface of North America, which is computed to have an average height of 748 feet, the whole of this half of the continent would be reduced to the sea level in about 4,500,000 years. Such calculations are of importance in showing that the present surface of the land must be continually changing, and cannot, therefore, be comparatively of high antiquity.

23. Deposit.—All rivers, then, are constantly busy grinding down and transporting gravel, sand, and mud over the surface of the land. To ascertain what becomes of all this material, let us follow the course of a river from the mountains to the sea, and watch how the sediment is disposed of by the way.

24. When running water has its velocity checked it loses some of its power to transport sediment, which then partly sinks to the bottom. This may happen when a stream enters upon a gentle slope or plain, where it must move more slowly, or when it joins a larger and more gently-flowing current, or when it falls into still water, like that of a lake, or into the sea. Hence, during its course as well as at its termination, a river necessarily encounters many obstacles to its progress, by which it is compelled to slacken its pace and to drop some of its sediment.

. Beginning among the mountains, we meet with ·ant examples of this arrest of the detritus which

the torrents have been sweeping down the declivities. A steep slope may be deeply trenched with gullies which have been cut out of the soil or rock by the torrents. But wherever these ravines reach a strip of more level ground they each show a pile of rubbish, which the headlong brooks, checked in their flow by the change in their angle of descent, have been forced to throw down. In a long, narrow valley among lofty mountains, so numerous may be the torrents, and so vast the heaps of gravel and stones which they tear out of the hill-sides and heap upon the bottom of the slopes, that it may be difficult to maintain a roadway, which is liable at one point to be buried under huge masses of debris, and at another to be swept away by a flooded stream.

26. But only the larger and coarser kind of sediment is usually arrested at the foot of these mountain slopes. The finer parts and even some of the rougher gravel are carried further into the valley, where the various brooks unite into one main stream. At every point where this stream is checked, an accompanying deposit of sediment occurs. Among its many serpentine windings the current, though rushing briskly round the sharp side of a bend, is thrown into an eddy or slack water at the concave side, and there you find a bank of sand or shingle.

27. When the stream is flooded it not only fills its ordinary channel, but rises, and overflows the flat meadows on either side. These tracts of level ground diminish the velocity of the overflowing water, which must therefore allow some of its sand and mud to fall upon them. Should they be covered with herbage or brushwood, the leaves and branches act as filters to retain the sediment. So that when the stream has subsided the inundated ground is found to have received a coating of fine silt, or even, it may be, of coarse gravel.

28. If, then, each flood adds to the height of the level

ground on either side of the stream in a valley, the time must come when, even at the highest flood, the water will not be able to overspread the plain. This would arise not only from the heightening of the plain by such frequent deposits of sediment, but from the gradual deepening of the stream-channel by the scour of the current. As the channel is deepened the current will continue as now to eat into its banks, curving from side to side, and forming a new plain at a lower level. This process has been in progress for a long time in most river-valleys. A succession of terraces marking former levels of the river-floods may be seen rising even up to heights of several hundred feet above the present river. The accompanying figure (Fig. 63) represents a section drawn through one of

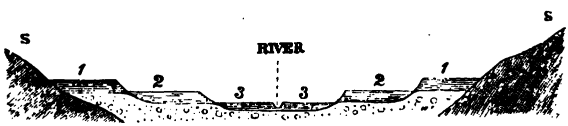


FIG. 63.—Terraces of gravel, sand, and mud, left by a river.

these river-valleys, and shows the relation which the low level terrace (3) at present in course of formation bears to the higher and of course older ones. In some of the latter, remains of primitive man, such as chipped stone spear-heads and other implements, have been met with in different parts of Europe, showing that when the rivers flowed at the level of these higher terraces, a rude human population already existed in countries where certainly the river-valleys have undergone hardly any appreciable change within historic times.

29. While still in the mountainous or hilly part of its course, a river may have to traverse one or more lakes. Each of these sheets of still water arrests the current and

compels it to drop its burden of sediment. As we saw in Lesson XXVI., lakes filter the river-water, which, leaving on their floors its sand and mud, issues at the lower end quite clear. It is where the river enters the lake that the chief deposit takes place. By degrees that portion of the lake is filled up and converted into a plain which, after being gradually heightened by the river-floods, at last comes to be above the flood-limit. In this way the upper end of the Lake of Geneva has been so diminished by the deposits of the Rhone that a Roman port, still called Port Valais, is now nearly two miles from the edge of the lake, the intervening space consisting of meadows and marshes.

30. If no other agency should intervene to keep them open, lakes must evidently in course of time be filled up by the earth and sand washed into them. This has already been the fate of many. The once united lakes of Thun and Brienz in Switzerland have been separated by the tract of land formed by the streams at Interlaken. In Great Britain, as well as generally throughout Northern Europe, every stage in the disappearance of lakes is abundantly shown, from the mere tongue of sand encroaching upon the edge of a deep mountain tarn up to the flat moss or fertile meadow which marks where a former lake has been silted up.

31. When the river enters the lowlands the diminished slope of its course causes it to flow with a weaker current, and therefore to drop some of its burden of mud and sand as it moves along. Winding to and fro, it cuts down its banks at one part and heaps up sediment at another, so that in course of time the whole of a wide plain comes piece by piece to be levelled by the shifting stream. The plain is formed indeed out of the sediment which the water has carried down from the higher ground. A well or pit sunk anywhere over its surface shows that beneath the s

there lie layers of water-worn silt, sand, or gravel, like the materials now being transported and deposited by the river.

32. When the plain is long and the seaward inclination slight, the flow of the river may be so lazy that instead of scouring out its channel it may be unable to prevent the sediment from sinking to the bottom and actually heightening the bed of the channel. During floods, too, the chief deposit of silt takes place on the banks on either side of the river; consequently, as the ground there is raised in level more than the plain beyond, which receives less sediment, the river gradually comes to flow at a higher level between broad embankments of its own building. From time to time it breaks through the lower or weaker parts of those embankments and inundates the plain, perhaps even scouring out here and there a new bed. In cultivated regions, like those watered by the courses of the Po and Adige, in the plain of Lombardy, and by the lower portion of the Mississippi, much care is needed to strengthen the banks, with the view of averting floods. The rivers have sometimes so heightened their channels that the surface of the current flows during floods at a higher level than the streets of towns on their banks.

33. As a familiar example of such broad plains formed by the accumulation of sediment brought from the interior of the land and laid down by the long-continued flow and overflow of rivers, we may take the valley of Egypt, which is a river-formed plain laid down between two ranges of higher ground. In Lower Egypt at midsummer every year the Nile begins to rise and cover the flat land on either side of its course. The inundation is at its height in about three months, and then the waters, after remaining stationary for nearly a fortnight, retire to their former level. This annual rise corresponds (as mentioned in Lesson XXV., Art. 18) to the rainy season in

the mountainous table-land of Abyssinia. When the monsoon blows from the Indian Ocean it brings torrents of rain, which rush down the rugged slopes of that country and sweep along a vast amount of mud. Thousands of swollen and muddy streams are at last united in the Blue Nile, which carries this vast body of discoloured water down into Egypt. After the inundation has ceased the ground is found to be covered with a thin coating of rich fertile mud left by the water. It has been estimated that the thickness of this annual deposit does not exceed that of a thin sheet of pasteboard, so that a depth of only two or three feet of the soil of Lower Egypt represents the continuous deposits of a thousand years. The increase of the Egyptian plain evidently takes place at the expense of the high grounds of Abyssinia. It is the finer particles, worn away from the rocks of these uplands, which form the mud spread over Egypt. Here we see how the erosion, transport, and deposit of materials by running water combine to build up a plain and renew its fertility.

34. The great plains of India furnish likewise admirable illustrations of the way in which the debris of the mountains is spread out by rivers on the low grounds. The valleys of the Indus, Ganges, and Brahmaputra have been filled up by the accumulations carried down from the Himalaya chain by these great rivers. The Tigris and Euphrates have likewise combined to fill up the upper half of the valley of which the Persian Gulf is the still remaining lower half. On the American continent this process is exhibited on the most stupendous scale. Most e eastern coast-line of the United States is a plain ed by the deposit of sediment washed off the land. alley of the Amazon, with its vast forests or *silvas*, so long and so level a plain that ships can sail up er to the very foot of the Andes, a distance of 2,000 inland from the sea.

35. We have now, lastly, to see how the sediment borne down by rivers is disposed of when it reaches the sea. Many rivers have at their mouths what is called a bar, that is a ridge of gravel or sand stretching across the channel, and always under water. From what has been said already in this Lesson, the origin of this bar will now be understood. It is evidently due mainly to the arrest of the sediment where the current of the river is checked by coming in contact with the sea. The coarser gravel and sand which have been pushed along the bottom of its channel by the river now encounter the opposition of the salt-water, over which the lighter river flows onward. The sea too piles up fresh materials upon the bar from the outside, while, on the other hand, the river when flooded drives its bar further seaward. Hence this barrier to navigation at the mouth of a river is continually shifting its position and altering its shape and size, according as the action of the river or that of the sea predominates.

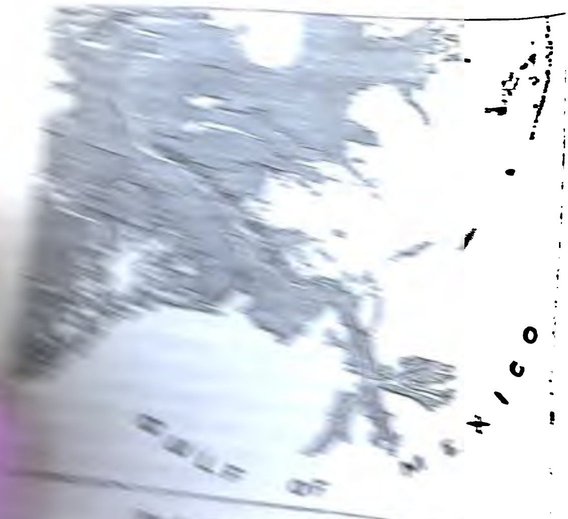
36. Some of the larger rivers of the globe carry out at their mouths on a vast scale the same kind of action which was described as going on where streams enter lakes. The sediment deposited in the sea has gradually increased so much as to fill up the bay or gulf into which the river originally flowed, and to convert it into a territory of flat land. This advancing tract of river-formed ground is usually triangular in form, the apex pointing up the river. It was this resemblance to the Greek letter Δ that suggested the name of delta, as applied to these accumulations at the mouths of rivers. Down to the head of its delta a river usually is augumented by tributaries from either side, and does not branch, except for a limited space, as where it encircles an island in its course. Its current thus becomes more and more ample. But when it reaches the delta it begins to subdivide, and continues to branch out until in some cases the flat plains and marshes

are traversed by innumerable tortuous channels of water. By this ramification over the flat ground the deposit of sediment is facilitated, consequently the channels are being continually filled up, while new ones are cut through the soft earth and silt. Two or more main branches of the river carry out the chief part of the water and sediment to sea, and at their mouths the increase of the delta is most apparent.

37. The accompanying figure (Fig. 64) shows the shape of the lower part of the delta of the Mississippi, and the way in which the tongues of low muddy swamps are pushed outwards into the Gulf of Mexico. The average rate of advance of the delta has been estimated to amount to 86 yards in the year. The Tiber throws forward its delta at the annual rate of about 12 to 13 feet. The delta of the Po has increased at such a rate that the port of Adria, which stands on it and was so important in Greek and Roman times as to give its name to the Adriatic sea, is now 14 miles inland.

38. Since this action must have been in progress for a vast number of centuries, we may be prepared to find that some deltas are of enormous size. That of the Mississippi embraces an area of about 40,000 square miles. That of the Ganges and Brahmaputra is as large as the whole of England and Wales. Their vast superficial extent indicates of course the high antiquity of these deltas. But we must remember also that as they have been formed by the gradual filling up of gulfs of the sea, where these gulfs were deep a prolonged period of time would be occupied in bringing up the level of the bottom to that of the surface before any advance of the plain of the delta could take place. Where the tides and currents of the sea interfered to sweep away some of the sediment, the time required would be still further increased. The delta of the Ganges has been bored into at Calcutta, and

... sand, gravel, silt, and ... layers of ... the mouths and



Lesson XXVIII.—The Frozen Waters of the Land.

Frost, Snow-fields, Glaciers.

1. In Lesson X. we traced how the moisture of the air, when the temperature sinks to the freezing-point, passes into ice. We have now to see what becomes of this ice when it falls from the air to the land, and how the waters of the land are affected when they too are cooled down below the freezing-point. Changed into solid ice, they cannot but acquire new and different powers from those which have been the subject of the last four Lessons. What part then does the frozen water of the land play in the general plan of the globe? We shall find some answer to this question by considering three aspects of the ice of the land—Frost, Snow-fields, and Glaciers.

2. **Frost.**—Most substances suffer contraction from cold, and consequently increase in density. A cubic foot of pure water, for example, at a temperature of 40° Fahr. weighs more than the same quantity at 60°: or, in other words, a vessel exactly filled with water at 60° would be found to be not quite full were the water cooled down to 40°.

3. But a remarkable change takes place during the further cooling of the water. When the temperature reaches 39·1° Fahr., contraction ceases. This is, therefore ... temperature at which pure water is heaviest, and ... point of *maximum density* of fresh-water. ... nt the water *expands*, and instead of ... *ns on the surface of the wa*rmer layers, ... last converted into ice when the tempera- ... n to 32°. *Hence it is that ice is* forr

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go-rounds and other amusements, so that the busy concourse of people was called "Frost Fair."

5. The freezing of sheets of water on the land may take place so equably, and the ice may disappear again so quietly, that after the frost has passed away no trace may be left of its having occurred at all. But should a frozen lake break up under a storm of wind, large masses of ice will be driven ashore and may push up the sand, gravel, and stones lying at the water's edge. Such heaps of ice often take some weeks to thaw, and after they have melted, the stones and sand which they had driven ashore are found scattered over the ground. This can be seen on a great scale on the shores of the large Canadian lakes in spring, where also another result of the severe frosts may be observed. Blocks of stone lying in shallow water are frozen in the ice. When a thaw comes and the ice breaks up, they are actually lifted from their places by the fringes of ice which have formed round them, and are floated away to some other part of the shore, or may even be driven out into the deeper water, so as at last to be dropped there. This transport of stones may be watched along some of the rivers as well as the lakes of Canada. It has been particularly observed on the shores of the St. Lawrence.

6. But the effects of the fall of temperature in winter are not confined to large sheets of water on the land, and indeed it is not there that the most remarkable results of frost are to be observed. We have seen how the rain which falls upon the land soaks through the soil and rocks. Both soil and rocks therefore contain abundant water in their pores and cavities. When severe frost sets
water freezes. The soil becomes consequently
that even muddy places where we should have
p in mire can now be safely and easily traversed

7. Let us consider the consequences of the freezing of the soil. When a jug of water is exposed to severe frost it is apt to be split. And often in insufficiently warmed dwelling-houses water-pipes in the same way burst during frost. The reason of these mishaps is to be sought in the expansion of water in the act of freezing. When passing from the liquid to the solid state, water undergoes a sudden and remarkable expansion, amounting to about one-tenth of its volume. At the moment of change it exerts great force upon the sides of the vessel or cavity containing it, and if it cannot readily escape it will do its best to burst these sides, that it may find room for its increase in bulk. Now what takes place in a water-jug or pipe goes on also among the little particles of water inclosed among the grains of the soil and the rocks. The frost expands them, and they push these grains aside. On a winter morning after a night of sharp frost we may notice that the expansion has been great enough to force the little pebbles and stones of a roadway out of their places. So also, in countries like Canada, where the winters are extremely cold, wooden fences are in the course of a year or two twisted out of the ground.

8. It is not until after thaw that we are made fully aware of what the frost has done. So long as the cold continues the separated particles of soil are kept together by the ice, which binds them into a hard solid mass. But when this ice melts, the grains of sand and earth become loosened from each other. Walking on a road or over a ploughed field after frost, we find that this loosening has been carried so far that the ground has become coated with mud. Indeed the millions of little ice crystals, which the frost wedges in among the grains of the soil, have much the same effect as if the earth were ground down in a grinding-mill or mortar. They pulverise

it, that is, reduce it to powder, and thus lay it more open to the branching roots of plants which obtain so much of their sustenance from the soil. Farmers are in the habit of ploughing their land before the cold weather sets in, and leaving the upturned loam exposed to the beneficial effects of the succeeding frosts.

9. The powerful mechanical effects of frost are so well seen in soil owing to the abundant moisture retained among the particles of which the soil is composed. But any porous rock which contains sufficient water, and is exposed to a great enough cold, may show the same kind of disintegration. Hence in countries where the winters are severe, ordinary building-stones and mortar are found to peel off in successive crusts, or to crumble down into powder after the frosts have given way to milder weather. Even in the comparatively mild winters of Britain this may be constantly seen; in the severer climate of North America it is a serious and costly evil, since it prevents the use of many kinds of building-stone, which in the absence of frost would be very valuable.

10. Passing now from the water retained and frozen among the pores of the soil and of rocks, let us consider further the result of the formation of ice in the larger cracks and crevices of cliffs and crags. To realise properly how abundant these natural lines of division are in all rocks, look at any exposed face of rock such as a sea-cliff, the ravines of a river, or the precipitous sides of a mountain. No matter what may be the kind of rock, you will find that it is traversed by many parallel or intersecting divisional planes or "joints." We saw in Lesson XXIV. that these lines are made use of as channels by which the surface water descends underground, and by which it re-ascends to form springs. When a frost comes, severe enough to penetrate beyond the mere outer layers of rock, the water contained in the external parts of the

joints freezes. It often happens that this takes place in cavities where there is little room for expansion, and where therefore the ice exerts its great force in pushing the walls of the joints asunder. Winter after winter the process is repeated, until at last the portion of rock on the outside gets so far wedged off from the rest that it loses its balance and falls with a crash to the bottom of the cliff. In all countries subject to intense frosts the bases of cliffs and crags may be seen to be strewn with large rough blocks, which have in this manner been loosened from their pl[illegible]s above[illegible] Among the valleys of mountains which ris[illegible] above the snow-line the operations of frost are [illegible] in splintering the crags and pinnacles, and giving t[illegible]e sharp spiry forms they so often assume. (See Less[illegible] XIX.)

11. Snowfields.—Wherev[illegible]e land rises above the snow-line it is buried under a permanent sheet of snow, from which only the higher and steeper mountain peaks project. In some regions, as in the table-land of Norway, the broad and tolerably level surface of the ground allows the snowy covering to spread in a vast undulating sheet three or four thousand feet above the level of the valleys. Standing upon one of the heights at the edge of such an expanse of snow, you see what looks like a white frozen plain, with no limit save the line where it meets the sky. In other parts of the globe, where rugged groups of mountains tower above the snow-line, and there are consequently no such level tracts, the snow accumulates in the hollows and on the higher slopes. The semicircular ranges of mountain cliffs and crests often inclose vast basin-shaped depressions, each of which becomes a gathering place for the snow. To all the permanent sheets of snow, whether occurring on table-lands or on mountains, the general term of snow-fields is given.

12. In these regions, since the moisture falls from the

air as snow rather than rain, and the heat of summer is insufficient to melt it all, the quantity of snow would increase indefinitely were there no provision whereby the surplus could be removed. The thickness of snow on some snow-fields must amount to many hundred feet. Greenland, for example, is almost wholly buried under one vast snow-field, so deep as to cover over the inequalities of the surface of the land almost as completely as the furrows of a ploughed field are lost beneath a heavy snow-wreath.

13. There are two ways, besides melting and evaporation, in which the snow-fields get rid of their excess of snow; these are avalanches and glaciers. Where the edges of a snow-field overhang steep slopes, portions of the more or less consolidated snow from time to time break off and rush with a noise like thunder and a terrific force into the valleys, tearing up the soil, sweeping down loose blocks of stone, uprooting or breaking trees, and carrying destruction as far as they reach. These snow-falls are called avalanches. In Alpine countries forests which lie in the pathway of such descending masses of snow are carefully preserved as barriers to protect the meadows and villages from ruin. Roads which pass along the base of snowy mountains require in some places to be covered over with a strong archway of masonry to protect them from the disasters caused by frequent snow-falls, which would not only sweep away every traveller and carriage in their course, but would even tear up the road itself, or bury it under heaps of earth and stones.

14. Glaciers, however, are the chief means whereby the superabundant snow above the snow-line is removed. While the snow forming the surface of a snow-field is loose and open in texture, like that which covers the ground in winter and disappears in spring, the under portions become more and more close and firm und

the increasing pressure of the overlying mass. This compacted snow (*névé* or *firn*, as it is called in Switzerland) passes by degrees into clear blue ice, as the imprisoned air is more and more completely squeezed out of it. If the snow-fields lay on perfectly level table-lands, there would be no general movement of the snow except along the edges of the plateaux, where the gathering snow-sheet would break and slide off in fragments into the valleys. But since the ground usually has a marked inclination

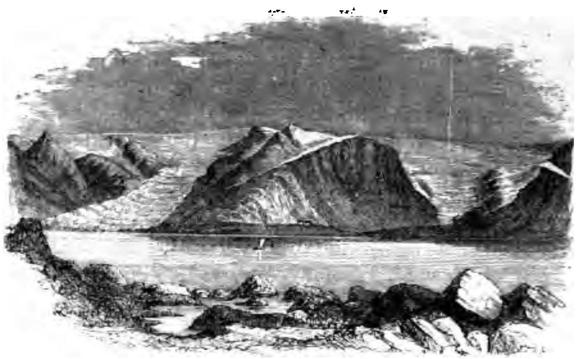


FIG. 65.—Snow-field and glaciers of Holands Fjord, Arctic Norway.

away from the axis or water-shed, the snow, by virtue of the action of gravity, is forced to slide downward even upon a very gentle slope. It is during this movement that the air is chiefly pressed out, whereby the loose white, opaque snow is converted into solid, blue, transparent ice. Having acquired this slow-sliding motion, the mass of snow must needs seek the lowest levels. It therefore moves downward into the heads of the valleys, which ascend into the snow-fields. Each of these hollows

becomes a receptacle in which the snow, pressing downwards from each side as well as from behind, accumulates to a great depth, and is so jammed up between the mountain slopes as to take the form of solid ice from top to bottom. Driven onwards by the pressure of the advancing mass behind and by its own gravity, this ice fills up each valley sometimes to a depth of several hundred feet, and for a distance of many miles. Such a tongue of ice, proceeding from a snow-field above and protruding below the snow-line down a valley, is termed a glacier. In the accompanying drawing (Fig. 65) two glaciers are seen descending from one of the great snow-fields of Arctic Norway. In one case the ice almost reaches the sea; in the other the glacier is smaller, and does not proceed so far from its parent snow.

15. A glacier, then, represents the escaping drainage of the snow-fall above the limit of perpetual snow, as a river does the surplus drainage from the rain-fall on lower grounds. Its size must depend upon that of the valley and the extent and declivity of the snowy gathering ground from which it issues. In the Alps, for example, the Great Aletsch Glacier extends about fifteen miles down its valley. Sometimes a little glacier fills up a high recess on the flank of a mountain, and never reaches even to the nearest valley. In other cases the glacier descends far below the snow-line, even into the region of meadows, corn-fields, and gardens. The lower glacier of Grindelwald, in the Bernese Oberland, reaches to a point about 3,500 feet below the snow-line on the north side of the Alps.

16. To realise as clearly as possible the general appearance presented by a glacier, let us suppose ourselves placed at the lower end of one of those among the Alps. On either side of the valley the slopes are clothed with pine, patches of green pasture catch the sunlight in the

hollows and on the lower projecting hills ; while around us lie scattered cottages and bright meadows. In front stands the abrupt end of the glacier—a steep, but broken slope of ice, from the base of which issues a river of pale muddy water. Numerous large blocks of rock are scattered about on the valley-bottom below the ice. The ground there, indeed, is mainly composed of coarse shingle, like

Fig. 16. View of a glacier, with its lines of rubbish (moraines) and the river which escapes from its end. Ice-worn hummock of rock and transported stones are shown in the foreground.

that which forms the bed of the present river. Even on the ice itself we may see heaps of stones, some, perhaps, poised just on the verge of the last steep slope of the glacier, whence they must soon roll down to join the crowd of others which have preceded them. Looking into one of the deeper rents in the ice, we see it to

be of wonderful purity, and of the most exquisite blue colour. And yet most of its outer surface is so obscured by earth and stones, that at first, perhaps, we can hardly be persuaded that this same clear, transparent ice really lies below.

17. We ascend to the surface of the glacier either by mounting among the broken cliffs of ice forming its abrupt front, or by choosing a safer and easier path up the slope on one side of the valley. The ice is now seen to lie as a great sheet filling the bottom of the valley from side to side, and stretching far up into the heart of the mountains. Its surface has at first a gentle slope, and is comparatively smooth, though many glaciers even at the lower end present a marvellously rugged aspect, like that of a tempestuous sea suddenly frozen. The ice is much obscured in places by earth, gravel, and stones which cover it. As we ascend the valley we notice that these surface accumulations are especially abundant along the sides of the glacier, and likewise in one or more ridges along its centre. During the day, when the sun shines out warmly, the surface of the ice is thawed, and consequently abundant little runnels of water flow over it. At night, when these are frozen, the glacier becomes once more silent.

18. In several respects a glacier resembles a river; and this resemblance is closer than might at first appear. If the position of any prominent object on the surface of the ice be observed with relation to some fixed point on the bank, or if, as in the original survey of the Mer-de-Glace by Professor James D. Forbes, a transverse series of stakes be driven into the ice across the breadth of the glacier, and their position observed at intervals from the bank, the ice is found to be slowly moving down the valley, and faster in the centre than at the sides, because the friction of the sides impedes the flow. The average

rate o[illegible]nt on the Mer-de-Glace was thus ascertained to b[illegible]uring summer and autumn, from 20 to 27 inches in the twenty-four hours at the centre, and from 13 to 19½ inches at the side.

19. Bending from side to side, and travelling over an uneven floor, the glacier is split across by rents called *crevasses*, which often open and form wide and deep chasms, extending down to the very bottom of the glacier. Stones and earth lying on the surface of the ice frequently fall into these fissu[illegible] reach the floor of the valley below the gla[illegible]risoned in the ice when the sides of the ya[illegible]s are pressed together again as the glacier mo[illegible].

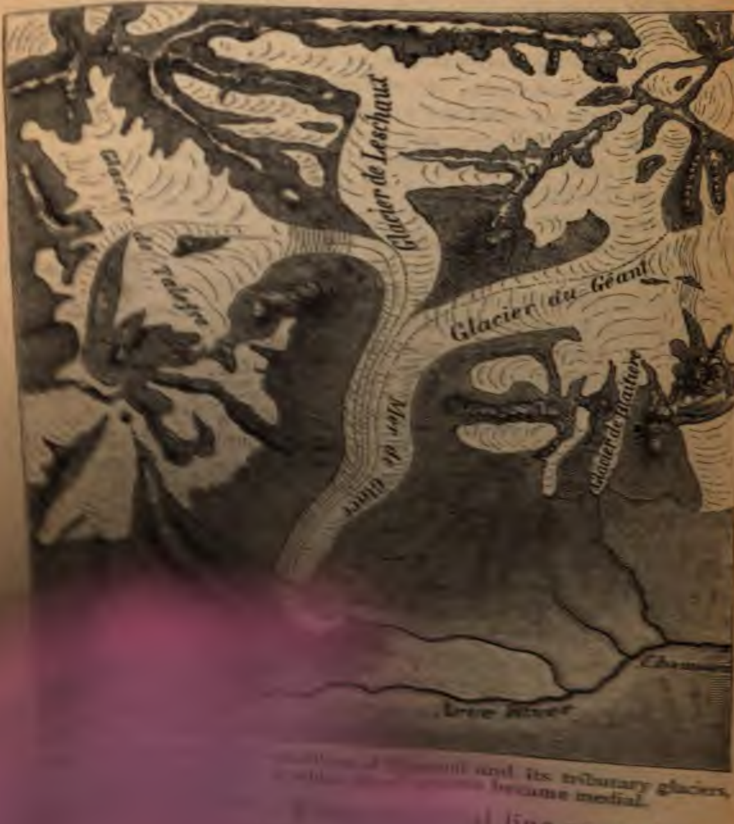
20. When a river r[illegible]eep and rocky part of its bed, it forms a rap[illegible]omes to a cliff, it takes the shape of a wat[illegible] not having the same mobility as running water, cannot so easily adapt itself to the irregularities of its channel. But it shows these irregularities in a very marked way. In the course of the glacier which we have supposed ourselves to be visiting, after, perhaps, some miles of slow ascent, we come to a precipitous slope, where the ice, completely shattered by innumerable fissures, rises into pinnacles and sharp crests of many fantastic forms. Could we watch that tumultuous descent of broken ice for a long enough time, we should find it to be all in slow motion downwards. It is an ice-fall, and answers in the mechanism of a glacier to the water-fall in that of a river. Underneath it the bottom of the valley is steep or precipitous, and the ice, unable to descend the declivity in one unbroken sheet, is cracked and splintered in this wonderful way. But just as a river, no matter how much it may have been tossed into foam by its descent in a water-fall, speedily takes its usual shape and rolls onward as if no sudden plunge had so recently disturbed its current, so a glacier, though it

may have been reduced, as it were, to fragments at one of these ice-falls, soon reunites at the bottom, and again pursues its course as a solid and continuous sheet of ice. If the glacier is a large one it may receive tributary glaciers from valleys on either side. The Mer-de-Glace of Chamouni, for example, is formed by the united mass of several glaciers, as shown in Fig. 67. Each of these, as well as the main stream, may be traced upward until it is found insensibly merging into the snows which fill up the hollows in the higher part of the mountains.

21. One cannot trace the course of a glacier and realise on the ground the size and character of those vast tongues of ice which carry off the drainage of the snow-fields, without wishing to know more of the work done by them. The rivers which bear away the surplus water of the land are busy in a stupendous work,—wearing down the mountains and valleys, and strewing their debris over the plains, or sweeping it out to sea (Lesson XXVII.). Glaciers, too, are engaged in a similar task. They transport the waste of the mountains down to lower levels, and they evade the sides and bottoms of the valleys in which they move.

22. Transport.—We have already noticed that a glacier is largely covered with earth and stones. Whence come these materials which so darken and obscure the surface of the ice, and which, far below the snow-line, where the glacier melts almost at the edge of the meadows and gardens, lie piled in heaps on every side? From a good point of observation above the glacier you may notice that the heaps are not scattered wholly at random across the surface of the ice; but that there are long lines of stones which keep apart from, but parallel to, each other, and run along the length of the glacier. You see them winding to and fro with the varying curves of the glacier in its course until they are lost in the distance.

In the drawing of a glacier in Fig. 66, for example, some of these lines of stones are seen both in the centre and



[illegible] and its tributary glaciers, [illegible] became medial.

[illegible] l line on a glacier [illegible] n the middle), and

you will find at last that at some higher part of the valley it brings you to a point where two branches of the glacier join, and where the line of stones either continues up the side of one of the branches, or divides into two, one portion keeping to the right-hand side of one of the tributary glaciers, the other remaining on the left-hand side of the other branch (Fig. 67). In every case you will observe, if you trace the glacier far enough up its valley, that a line of stones in the middle of the ice comes really from the side, and is due to the confluence of two branches of the glacier. Owing to the irregularities in the slope and breadth of the glacier-channel, and the manner in which the ice is consequently driven to adapt itself to these, as well as to the melting of the surface of the glacier (Art. 25) the lines of stones are apt to lose their distinctness as they advance down the valley, until, after some great ice-falls and abundant crevasses, the rubbish comes to be spread more or less over the whole of the glacier's surface, as it is towards the lower end of the Mer-de-Glace (Fig. 67).

23. These heaps of stones, earth, and gravel lying on the ice are known by the name of moraines. When on the side of the glacier, they are termed *lateral* moraines; on the centre, they are called *medial;* at the end, where the glacier throws down its burden as the ice melts, they are spoken of as *terminal.*

24. In all cases, then, these moraine-heaps can be followed up the glacier to the base of some cliff or craggy mountain-slope, whence the blocks of rock have been derived. In such positions you see how the fragments have been loosened by the severe and prolonged frosts of these high grounds, until, wedged off from the face of the cliffs, they have rolled down to find a resting-place upon the glacier below. Once on the ice, they are slowly borne down the valley and dropped among the heaps of

rubbish at the far end of the glacier. Much of the rubbish, however, falls down the numerous rents or crevasses in the ice, and reaches the bottom of the glacier, there to aid the ice in accomplishing another important part of its work (Art. 28).

25. It is curious to watch the progress of one of the large blocks as it travels with the ice. We thereby learn, what might not otherwise be so evident, that the surface of the glacier is continually being lowered by melting and evaporation. Take the case of a large flat stone, which, bounding from some high crag, has found a lodgment upon the ice. The portion of the ice lying below

FIG. 68.—Glacier table—a pillar of ice supporting a block of stone.

the stone is screened from loss by thawing and evaporation, but the surrounding parts of the glacier, not so protected, are insensibly wasted away. Consequently the stone begins, as it were, to rise out of the glacier. Its pedestal of ice continues to increase in height, but being exposed on the sides to sun and air, is lessened in diameter, until it becomes too slim to support the heavy burden of stone, which then tumbles down upon the surface of the glacier (Fig. 68). But as the general waste of the surface of the ice continues, the new position of the stone

is soon marked by the rise of a new pillar of ice as before. The same block of rock may thus in the course of its journey down the glacier become the capital of several successive ice-columns. The same kind of testimony to the remarkable lowering of the surface of the glacier is shown by the long parallel moraine mounds. Looking at one of these ridges, and even climbing and standing on it, you would suppose it to consist of fragments of stone throughout. But pull down some of the loose blocks, and

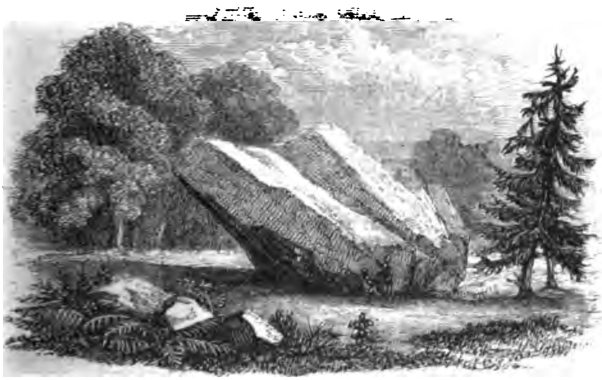


FIG. 69.—The Pierre-à-Bot, near Neufchâtel (J. D. Forbes).

you will discover that the solid ice lies immediately below. It is in fact a ridge of ice with a coating of debris which has protected it from the general waste, as the detached st... es ... e ice-pedestals beneath them.

valleys with glaciers in them large blocks observed above the present limits of the ...s to which at one time the ice evidently ... occur poised sometimes in the mo...

precarious positions, as if a man's strength would be sufficient to dislodge and send them down the slope. These perched blocks, as they are called, furnish good proof of the former extent of the glaciers. By their means, for instance, combined with other evidence, it can be proved that the glaciers of the Alps at one period filled up the Swiss valleys, and even spread over the broad plain of Switzerland between the Lake of Geneva and the Jura. On these vast ice-rivers blocks of granite from the Mont Blanc group of mountains were transported across what is now the valley of the Rhone and the Lake of Geneva, and were stranded high on the sides of the Jura range. The accompanying figure (Fig. 69) by the late Principal Forbes, representing one of these travelled blocks, erratics, or, as the Swiss call them, foundlings, shows the great size which some of them attain.

27. We conclude then that one important part of the work of glaciers is the transport of the materials of the mountains from higher to lower levels. In the case of such a mountain chain as the Alps or the Himalaya the glaciers melt long before they can reach the outskirts of the high grounds. They, therefore, do not bear their burden beyond the mountain region, though, as we have just seen, they once carried it much farther than they do now. But in Arctic and Antarctic regions the glaciers actually reach the sea-level, and even pushing their way out to sea, break off into icebergs, as already described (Lesson XVI.). The accompanying drawing (Fig. 70) represents the little glacier at the head of the Jokuls Fjord in the north of Norway, which descends into the sea. You observe a few transverse crevasses in it near the base. From time to time the outer portions break away and float slowly on the current of fresh-water which is moving down the inlet. Pieces of stone may now and then be seen upon these little bergs. In Green-

land vast glaciers, like the Humboldt glacier, which measures 60 miles in width, descend to the sea-level, and extend for some distance from the shore till their seaward ends split off and become icebergs. (See Fig. 16.) Occasional blocks of stone have been noticed on these bergs. The debris of the mountains is thus actually borne by the ice away out to sea, and may travel for

[illegible]—Glaci[illegible]nding to the sea. Head of Jokuls Fjord, Arctic Norway.

[illegible]y h[illegible]d[illegible] [illegible]iles before it sinks at last to the [illegible]tom [illegible]

28. [illegible] the second place, a little further [illegible]bservati[illegible] [illegible]fice to show that the carrying of material [illegible] valle[illegible] not all the work which the glacier [illegible] [illegible]nsider the river of muddy water [illegible] end of the ice. Muddy [illegible]ve [illegible] it is most copious and

discoloured during the warm dry weather of summer and autumn. The mud cannot come from the melting of the glacier itself, for the ice is clear and pure. It is not derived from the bright little brooks and torrents which come down from the melting snows and the springs on either side of the valley. Yet it undoubtedly comes out from beneath the glacier. Mud consists merely of the finer particles worn from rocks. There must, therefore, be a great deal of waste somewhere to account for this constant and plentiful supply of mud.

29. Following this inquiry further, we observe that the rocks which rise on either side of the valley from under the glacier are remarkably smoothed. Underneath the ice, as we may sometimes detect, the floor of the valley is similarly smoothed and polished. The contrast between the rounded and smoothed outlines of the knobs and hummocks of rock near the ice, and the sharp, rugged forms of the crags above, is often singularly well-defined. Besides this smoothing and polishing, the surface of the rocks may be observed to be covered with many parallel or intersecting scratches and groovings, varying from such lines as might have been graven by a hard grain of sand to such deep ruts as would require the forcible pressure of some sharp edge or blunt corner of stone. These markings are seen to run in a general direction down the valley. They have been evidently produced by some agent which has descended with sufficient force and steadiness to grind the rocks along the bottom and the lower slopes of the valley.

30. It is now and then possible to creep in under the ice at the end of the glacier, and to see where it rests upon its rocky bed. At such times you may, as it were, catch the glacier in the very act of grinding down and striating the rocks below it. Pieces of stone and grains of sand are jammed between the ice and the rock over which it

moves. Held there and pressed against the rock, they groove and scratch it. As this goes on year after year, the surface of the rock necessarily undergoes continual waste, and acquires that smoothed, polished, and striated appearance so characteristic of the bottom and sides of glacier-valleys.

31. Here, then, is the cause of the unfailing muddiness of the water which issues from the end of a glacier. The glacier is busily engaged in wearing down its channel with the same kind of grinding powder which a river uses—the sand and stones that fall into it from the

[illegible] 71.—Stone polished and striated under glacier-ice.

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32. We conclude, then, that another great task in which every glacier is ceaselessly engaged is the erosion of the sides and bottom of its valley. That this is an important work in regard to the general scenery of a country may be shown by the great height and the long distances to which the peculiar forms of ice-worn rocks may be traced. The former greater thickness and wider extent of the Alpine glaciers are not more decisively shown by the range of the erratic blocks than by that of the polished and striated rock-surfaces. By this test it can be proved that a great part of Northern Europe and America has been under moving sheets of land-ice, which, passing over th[illegible] mountain-ridge to sea-shore, have left beh[illegible] memorial in the almost indelible mark[illegible] the rocks.

33. Agai[illegible]he tumultuous body of discoloured [illegible] glacier without appreciating that in time a sensible deepening of the valley must take place in consequence of this ceaseless erosion and removal of materials. The deepening cannot be uniformly spread over the whole of the valley. There are places were the ice exerts more grinding power than at others, as a river at its falls and rapids effects more destruction than among meadows and plains. The rocks, too, of the glacier's bed vary much in hardness and power of resistance. Some parts must be more readily scooped out than others. So that, should the glacier retreat up the valley, these more deeply excavated portions, unless concealed under moraine rubbish, would become basins filled with water. Lake-basins of this kind in the midst of ice-worn rocks are a marked feature of glacier districts and of all those regions of Northern Europe and Northern America which have just been referred to as having been at one time buried under ice (see Lesson XXVI. Art. 4).

LESSON XXIX.—THE SCULPTURE OF THE LAND.

1. In Lesson XX. we traced the character of the leading features of the general external form of the land—its mountains, table-lands, valleys, and plains. At the end of that Lesson the question naturally arose whether any explanation could be given of the origin and history of these various features, but the answer to this question was postponed until after some consideration had been given to the nature of the materials and the internal constitution of the globe, and to the operations of water upon the surface of the land. We are now therefore in a position to return to the subject and to apply to the investigation of it the facts and deductions about the interior and exterior of the land which have come before us in the last eight Lessons.

2. At the outset of this interesting inquiry it should be borne in mind that the existing land consists of the higher parts (projecting above sea-level) of those ridges into which the exterior of our planet has been wrinkled during its gradual consolidation and contraction from an [illegible]inal fluid [illegible]ion (Lesson XXII. Art. 20). We must [illegible]ily co[illegible] [illegible]wever that the land, such as we now [illegible] [illegible]iginal surface of the globe. That [illegible] [illegible] evident from two considerations [illegible] [illegible] already been made. 1st. All the [illegible]ar [illegible] has been under the sea, and even [illegible]s ar[illegible] [illegible]s consists in great part of hardened [illegible]lt[illegible] [illegible]d, and [illegible]er materials, which were [illegible] upon [illegible]oor of the sea (Lesson [illegible] The [illegible] surface of the land is [illegible] [illegible] an[illegible] [illegible]ous though unequal

distributed decay and removal. A comparatively short period would suffice for the entire destruction of the continents were their surfaces to be continuously wasted even at the rate of the Mississippi's operations—and other rivers work considerably faster. At any probable rate of degradation the original land must have been long since destroyed, and we can hardly hope to find any trace of it even buried under the later accumulations of which the continents consist (Lesson XXVII, Art. 22).

3. But though no portion of the present land can be looked upon as part of the original or earliest solid surface of the planet, there can be no doubt that the existing continents must be very old. Not improbably they occupy the sites of the first ridges which appeared upon the cooling and shrinking mass of the globe. In the course of ages these primeval ridges would be worn down by the action of water and air. But from time to time, if renewed uprisings took place along the same original lines, the land would be formed and destroyed, and then formed and destroyed again. That this is not mere theory, but rests on a strong basis of probability, may be shown by a consideration of the way in which the materials forming the land have actually been put together. If the existing ridges can be shown to have been upraised again and again during past ages they may at least be plausibly conjectured to mark generally the primeval lines of elevation on the surface of the globe.

4. Let us then return to the composition of the earth described in Lesson XXI. All over the globe it is found that by far the largest mass of the land is built up of materials which have been accumulated slowly as sediment on the floor of the sea. These materials are arranged in layers or strata which have been laid down upon each other until a depth of many thousands of feet has been formed. It is evident that the original position of these

strata must have been nearly or quite horizontal, seeing that they were piled one upon another as sand and mud are laid down on the level or gently sloping bed of the sea at the present time. The subterranean movements by which they have been raised above the sea into dry land have taken place over such wide regions that this original level or gently inclined position may remain little or not altered. The flat bedding of the rocks shown in Fig. 26 is of common occurrence, and most people will recognise the familiar look of such sections as that of the quarry

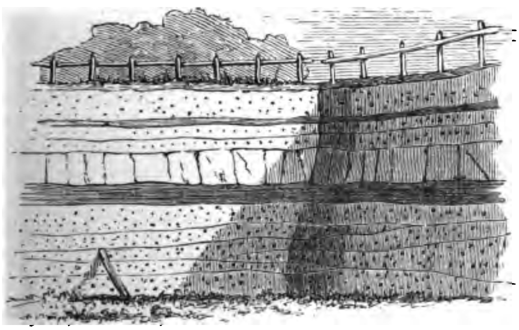

FIG. 72.—Quarry in flat stratified rocks.

sh In these cases we may conceive a large
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Fig. 73.—Section across a mountain-chain to show how the level rocks of the plains are bent and inverted along the flanks of the mountain, while the lowest and oldest rocks are made to form the central and highest point of the chain.

uniformly distributed over the surface. The vast basins of the oceans no doubt mark the regions where the subsidence has been greatest and most continuous. Probably they have been depressions from the beginning, though portions of them, particularly along their margins, have from time to time oscillated up and down. Every tract which sinks requires of course to accommodate itself to a diminished superficial area, and tends to exert a strong lateral thrust upon the adjoining more stable parts. Under the influence of this force long ridges have been raised into land between the ocean basins. Every successive subsidence may thus have carried with it a corresponding upheaval. So that although subsidence was the rule, and although the land was being continually wasted by air, rain, rivers, and the sea, nevertheless these periodic uplifts have compensated for the loss, and seem to have maintained, on the whole, the balance of dry land.

6. But it could hardly happen in the midst of these movements that the upheaval should be always so gentle and uniform as not to disturb the original level, or nearly level, position of the strata. On the contrary, over wide tracts of land, and more particularly along vast extended lines, the rocks have not only been upraised, but have been crumpled up and broken. Instead of remaining in horizontal or slightly inclined sheets, they may be found tilted

up in all directions, and often placed on end like books on a library-shelf. Every great mountain-chain furnishes examples of these more complex arrangements. On the plains and lowlands the rocks may stretch for hundreds of miles as level as before they rose out of the sea. But towards the interior they begin to bend in wave-like undulations, which increase in magnitude until, along the flanks of the mountains, the rocks are sometimes found actually so thrown over that the lowest lie uppermost. This structure is explained in the accompanying diagram (Fig. 73).

7. In this section, which represents an extremely simple form of mountain-structure, there is evidence of only one

FIG. 74.—Section across a mountain chain, showing two successive periods of uplift.

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mountain-chains which traverse it is due to the movements of the solid crust of the earth, it is clear that the present aspect of the land must have been largely determined by the action of those various agents which wear down its surface. The vast amount of mud annually transported into the sea by rivers, proves how much material is continually removed from the land, and therefore, how greatly, though it may be insensibly, the height and appearance of the mountains and valleys must in course of time be changed. This process of disintegration and removal is going on all over the globe, here more rapidly, there more slowly, but always advancing, and always bringing with it changes in the aspect of the land. In the lapse of the long periods of time during which it has been in progress, how vast must have been the mutations on the surface of the globe, how many successive mountain ranges may have been upraised and worn away!

11. We have followed the working of the chief agents by which the surface of the land is eroded—the air by its gases and vapours, its winds and changes of temperature; frost by its oft-renewed wedges of ice; rain, brooks, and rivers by their movement down the land, and their power to sweep before them the loosened debris; avalanches and glaciers by the fragments of stone with which they grind and polish the rocks of the valleys; the sea by the waves thrown incessantly against the shores which bound it. We may compare the general results of the co-operation of all these forces to the work of a sculptor. They are, so to speak, the different tools with which the framework of the land is carved. But the sculpture they achieve is never completed. It goes on continuously so long as the land remains above the sea.

12. At first it may seem almost incredible that the whole surface of the land, even the loftiest and stateliest

mountains, should thus be crumbling down. But the more we search for proofs the more clear and abundant do they become. We learn that whatever may have been the aspect of the land when first pushed out of the sea, it has been, and is now being, chiselled from its highest peaks down to below the tide-marks. Its cliffs and pinnacles are split up and grow more shattered and sharp every year. Its ravines are widened and deepened. Its hilly surfaces become more roughened and more deeply seamed by the lines which running water traces over them. Its valleys and plains are levelled and strewn with the debris washed down from the higher grounds.

13. In travelling from place to place you will do well to note as you go the proofs of this universal decay. While so doing you will not fail to observe that though the wearing down of the land may be traced more or less clearly everywhere, its rate and the changes of scenery which it brings with it depend very much upon the nature of the rocks of each region. Here again we may have recourse to the simile of the sculptor's work. The character of a statue depends not only on the design and manipulation of the artist, but also on the material employed. Out of a piece of granite or of pudding-stone, no matter what amount of genius and skill were bestowed on it, the same effect could never be produced as from a block of pure white marble. So we find that the hills, valleys, and mountains differ from each other in great measure according to the nature of the rocks of which they consist. In your journeys, whether in your own district or in other regions, you will find it not uninteresting or uninstructive to take note of the changes in the aspect of the scenery through which you pass, and to connect them when you can with variations in the character of the rocks.

14. Apart, however, from the varying nature of the materials, nothing contributes more to the character of

scenery than those lines of division or "joints" which have already been referred to as traversing all rocks. They serve as channels for the descent and reascent of subterranean water (Lesson XXIII. Art. 17). They are made

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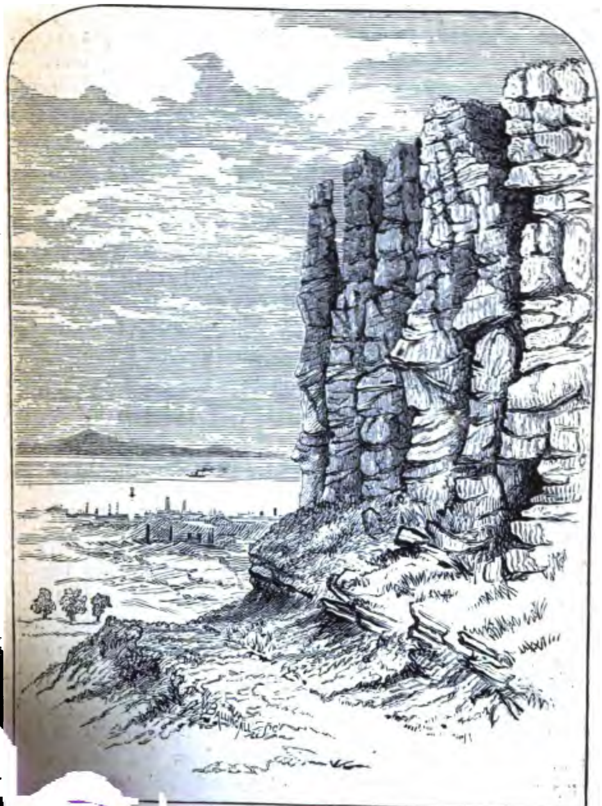
k which projects into
aracteristic outlines

the way in which its joints have been split open. Among the stratified rocks the joints allow vertical cliffs to be formed and large square buttress-like masses to project from the cliff or even to be isolated from them. The accompanying drawing (Fig. 76), for example, shows how the forms of coast-cliffs are determined by the position of the intersecting lines of joint, each vertical face of rock corresponding with the direction of one of these lines. Where such rocks form lofty mountainous ground they are often carved into the most picturesque forms of pinnacle and buttress. Again, among the unstratified rocks, such as granite and basalt, the influence of the joints is no less marked, as, for instance, where it defines the ledges and rifts in a precipice, or where it has allowed the most solid rock to be so completely shattered as to look like a huge mass of ruin. In Fig. 77 a representation is given of part of the face of a basalt cliff, where the abundant joints traverse the rock in such a way as to divide it into rude prisms, which are gradually wedged off from each other by frost, until, detached at last, they fall to the base of the precipice. The ruined masses below are further broken up and carried away piecemeal by frost, rain, and in the general process of "weathering," or in other cases, by the waves along the sea-shore or by the flow of a brook or river. Their removal permits the continuous decay of the cliff and preserves the steep face of the precipice, which thus slowly recedes as slice after slice is cut away from its front. But where the detached blocks gather at the base they form in the end a protecting bulwark there, and either retard or prevent the further recession of the line of cliff.

15. It is among the higher parts of the mountains that this kind of rude chiselling of the rocks can be most conspicuously seen. Not only are steep crags and lofty precipices formed, but the very mountain ridges are cut



the west front of Salisbury Crag, Edinburgh, showing of joints in promoting the splitting up of the rock (basalt), servation of a vertical face to the cliff.

away into sharp crests. These, again, still further split and splintered by the severe frosts and the furious storms of the mountain climate, are cut into slender pinnacles and spires, sometimes at a distance seeming so needle-like in their slimness and sharpness, as to have received among the Alps the name of *aiguilles*, or needles. It is the blocks loosened from these high crags and crests which furnish abundant stones for the glacier moraines (Lesson XXVIII. Art. 22).

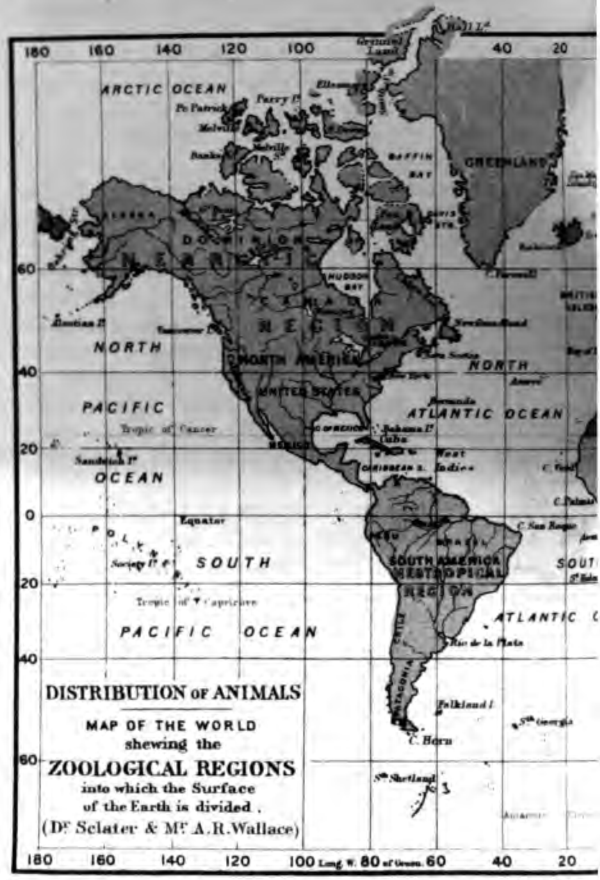
16. From the top of a high hill or of a mountain beneath the snow-line one may sometimes look down upon a wide region and mark, as in a vast map or model, how the little gullies on the sides of the slopes widen out into larger channels, how these run together into valleys, and how the whole landscape seems thus to be trenched with water-courses. When you have the good fortune to see such a scene as this, if you have already learnt to appreciate how ceaselessly and potently every brook and river is cutting out its channel (Lesson XXVI.), you will realise more vividly than from any map or description how the valleys are carved out by the power of running water. Every little gully and ravine down the steeper declivities around you is a sample of the way in which the forms of the solid land are changed; you may trace every gradation of size and shape from the trench that was opened by some storm last winter up to the deep and wide gorge through which the foaming river rushes, or the broad ample valley down which the collected waters from a whole range of mountains sweep onward to the sea. You may not be able to tell how far the line of any particular valley may have been originally determined by the shape which the ground had when it first rose out of the sea. But as a heavy shower of rain produces runnels which soon cut out a miniature drainage system on a road-way, so in the course of time the flow of

over the surface of the land must
ystems of valleys. You will feel as-
whatever might have been the original
rain and frost, brooks and rivers,
iers could not have been at work
nparatively short time without carv-
emselves, and sculpturing the moun-
and rugged forms as they now wear.
proofs of excavation; hill-sides are
, mountain slopes are trenched with
re cut down until they become only
rating the valleys which have been
Lesson XX. Art. 19).
ects of disintegration in roughen-
e land are most marked among the
sults of this process show themselves
gions in the strewing of the crumbled
lls over the valleys and plains. Every
eadow and level field bears witness to
the lowlands are smoothed and heightened
earth spread over them by the streams
m the hills. And yet this increase of the
plains does not really compensate for the
high-grounds. A little consideration of the
, in the first place, that though the plains do
siderable additions to their surface from the
swept down upon them by rivers, they receive
art of these materials, the remainder being carried
o sea by the rivers; and in the second place, that
the plains themselves are wasted; floods tear up
eir soil and sweep away their river-banks.

18. It appears, then, that the tendency of the process of sculpture, which gives to landscapes their characteristic details of outline, is in the end to reduce the dry land to the level of the sea. But this is not all. While th

general surface of the land undergoes attacks from the atmospheric influences, its margin is continually suffering from the assaults of the waves. It is indeed only the parts of the earth's surface lying under a considerable depth of ocean which are protected from decay (Lesson XVIII. Art. 19). Elsewhere the waves are gnawing away the coast line, or are only kept from doing so by the bar of detritus which has been thrown up against them.

19. Were no other operation to come into play, the natural and inevitable result of this ceaseless destruction would be the final disappearance of dry land. But here we see the meaning and importance of the underground movements already referred to as the results of terrestrial contraction; the great ocean basins have from time to time sunk down, and in so doing have pushed up ridges of land between them. These ridges on each successive uplift would consist mainly of the more or less consolidated debris worn away from their predecessors. The same materials have thus served over and over again to form the framework of the upraised land, and thus while looking at the subject from one side we see only ceaseless destruction, mountain and valley continually crumbling down before us, yet, when we take a wider view, we perceive that the decay of the surface is needed to furnish soil for the support of the living plants and animals which people the earth, and that the materials so removed from our eyes are not lost, but are carefully stored away to be in some future time raised into new land, and thereafter to go again through the same cycle of change.


DISTRIBUTION OF ANIMALS
MAP OF THE WORLD
shewing the
ZOOLOGICAL REGIONS
into which the Surface
of the Earth is divided.
(Dr Sclater & Mr A.R.Wallace)
ARCTIC OCEAN
BAFFIN BAY
GREENLAND
HUDSON BAY
NORTH AMERICA
UNITED STATES
NORTH PACIFIC OCEAN
NORTH ATLANTIC OCEAN
Tropic of Cancer
Equator
Tropic of Capricorn
SOUTH PACIFIC OCEAN
SOUTH AMERICA
NEOTROPICAL REGION
ATLANTIC
Falkland I.
C. Horn
Cuba
West Indies
Bahama Is
Newfoundland
Rio de la Plata
180
160
140
120
100 Long. W. 80 of Green. 60
40
20

burgh and London

CHAPTER V.

LIFE.

LESSON XXX.—THE GEOGRAPHICAL DISTRIBUTION OF PLANTS AND ANIMALS.

1. IN the foregoing Lessons we have considered the parts of the earth, their relation to each other, and the constant changes and reactions between them which constitute the Life of the globe. But above and apart from all these movements within and upon the surface of the earth, another kind of activity and progress now claims our attention, where the forces concerned are not air, sea, and 'and, but the living energy of plants and animals. Our anet is not merely a theatre for the evolution of physical enomena. It has been appointed as the dwelling-place a vast and varied series of living things, which move rough the air and people both land and water. The udy of the living organisms is comprised under the nera' Biology, or the science which deals with nal life.

tudy, opening up wide fields of inquiry far r which we have been travelling in these ds be subdivided into different depart- branch inquires into the structure and another deals with the way in wh

plants are distributed over the globe, a third treats of the structure of the various tribes of animals, a fourth follows the action of the different parts of an animal's body and the part which each of these plays in the life of that body, a fifth arranges the enormous numbers of animal forms in due order, to show their grade in the scale of being, and to allow the general assemblage of living forms in one region to be compared with that in another. These and the other branches of biology deal chiefly with the plants and animals as they are in themselves, or as they stand in relation to each other.

3. But it is evident tha[illegible] we ourselves are encompassed by external condi[illegible]eography, climate, and vegetation which, it may [illegible]onsciously, govern our everyday life, so each plant and [illegible]imal on the globe comes under the control of the san[illegible] surrounding influences. Apart therefore from the structure, or functions, or classification of vegetable and animal life, we may study it with reference to its relation to these external and dominant conditions. From this point of view physical geography and biology are seen to be closely linked to each other. It is impossible to gain any intelligent conception of the present distribution of plants and animals over the globe without entering upon inquiries which form part of the scope of physical geography.

4. We all know how greatly the plants and animals of different quarters of the globe differ from each other. The equatorial regions nourish a rank and luxuriant vegetation, including palms, bananas, tall tree-grasses with rope-like lianas twisting round their stems, and bright-hued, strangely-shaped orchids hanging from their branches. The animals are equally characteristic, for they include lions, tigers, elephants, rhinoceroses, camels, giraffes, crocodiles, large serpents, with crowds of gorgeously-plumed birds and brilliant butterflies.

5. The temperate zone is distinguished by a very different assemblage of plants and animals. The forests and woods show such trees as the oak, ash, elm, sycamore, beech, poplar, birch, hazel, and pine. The dells are bright in spring with snowdrops, anemones, and primroses; and in summer with speedwells, geraniums, and wild roses. But both the plants and the animals are more sober in colouring than in the hotter parts of the earth. The birds include the thrushes, larks, and other songsters. Among the wild animals of the low-ground we find mice, rats, weasels, hedgehogs, badgers, otters, foxes; and in hilly districts wild-cats, wolves, and bears.

6. Within the Arctic and Polar regions life becomes much less abundant and varied. As we advance trees disappear, though stunted forms of birch, fir, and willow extend a long way northwards. By degrees these too die out, and the scanty vegetation consists mainly of mosses, lichens, with saxifrages, gentians, and a few more flowering plants. These snow-covered lands are wandered over by polar bears, white foxes, reindeer, musk-oxen, ermines; the seas are frequented by seals, walruses, and whales; while the coasts are sought by large flocks of northern sea-fowl and by snowy falcons, buntings, ptarmigans, owls, and other white-feathered birds. At the extreme northern
nits r… by explorers, life of any kind is hardly to
e m… ng the deep snow-fields and piled-up heaps
ic… r nd and sea.

7. … n that from the extreme exuberance and
ri… and animal life in the equatorial and
… ere… dual diminution, until in the
… s w… st the zero of vegetation
… can be no doubt there-
… the distribution of plants
… armth being favourable,
… th of living things.

These regions, to which the following names and limits have been assigned, are shown in Plate X.[1]

10. (i.) Palæarctic Region, comprising all Europe with the temperate parts of Asia, and the tracts of Africa lying to the north of the Sahara desert; or the northern parts of the Old World, from Iceland to Behring Strait, and from the Azores to Japan. In the Arctic portions of this vast region the vegetation is comparatively meagre, showing an abundance of mosses and lichens, which in the tundras of Siberia cover thousands of square miles of barren waste. In favourable places flowering plants, such as saxifrages and gentians, peep out from beneath the snows during the short, but warm summer; stunted forms of willow, azalea, and rhododendon form here and there a kind of scrub upon the slopes, while southwards of the mean annual isotherm of 32° pine-trees make their appearance and increase in number, till they form wide ranges of dark forest, as in Norway, and on the higher mountain groups further south. Between the isotherms of 40° and 60° the sombre pine-forests, retaining their leaves throughout the year, give place to a more varied and luxuriant *deciduous* vegetation, which sheds its leaves in autumn and renews them again in spring. The trees include many noble kinds, birch, alder, beech, ash, oak, elm, sycamore, walnut, chestnut, and maple. Northern fruits, like the cranberry, cloudberry, bilberry, strawberry, currant, and raspberry, are succeeded further south by luscious pears and apples, almonds, olives, figs, grapes, and oranges. The cereals —wheat, barley, oats, &c.—are abundantly cultivated throughout most of the region. In the more southern countries, with a mean annual temperature, between 60° and 70°, the trees do not lose their leaves in winter. Here we find the evergreen oak, myrtle, laurel, with some plants,

[1] The arrangement here followed is that of Mr. Sclater, as modified by Mr. Wallace in his recent admirable work on "The Geographical Distribution of Animals."

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[illegible] and [illegible] the [illegible]

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14. (iii.) **The Oriental Region** includes Southern Asia from the mouth of the Indus along the southward slopes of the Himalaya mountains and the Chinese uplands to Ningpo, with Formosa, the Philippines, Borneo, and the Malay Islands as far as the south-east end of Java. Much of the surface of this region is covered with dense forests of tropical vegetation. Among the better-known plants occur the ginger, arrow-root, banana, cocoa-nut, screw-pine, yam, bamboo, rice, gourd, custard-apple, mango, coffee-tree, mangrove, ebony-tree, bignonia, hemp, and sandalwood.

15. The fauna contains some characteristic animals, the ourang-utan, long-armed monkeys, flying lemur, many civets, the tiger, hyæna, jackal, wild cattle, elephant, rhinoceros; many bright-feathered birds, as trogons, hornbills, goat-suckers, sunbirds, long-tailed parrots, and peacocks; numerous reptiles, including ground and tree-snakes, cobras, and crocodiles; and a vast assemblage of insects, among which the size and brilliancy of the butterflies and many of the beetles are remarkable.

16. (iv.) **The Australian Region,** embracing Australia, New Zealand, and the numerous islands to the east of Java, Borneo, and the Philippine group, consists wholly of islands, which, lying apart from all the great continental
... show a peculiar assemblage of plants and
ar ... st insular expanse of Australia, situated
... partly without the tropics, and exposing
...rior to the hot rays of the sun, while its
... shed by the open sea, presents contrasts
... the smaller islands of the
... and its proximity to the
... ental region, it contains a
... l fauna. Over the dry and
... neral heath-like vegetation
... d blue-green colour,

18. (v.) **Neotropical Region.**—Under this term are included the whole of South America, the islands of the Antilles group, and the tropical part of North America. Ranging across the whole zone of the tropics, and as far south as the 56th parallel of south latitude, and rising up to the snow-line in the Andes, this region presents many varieties of climate, which are well shown by differences of vegetation. The lower grounds within the tropics present the most luxuriant flora in the world. It abounds in mangroves, palms (cabbage-palm, ivory-palm, and other kinds), bananas, tree-ferns, and mimosas, growing in dense jungles, and having their stems and branches clustered round with many smaller plants, such as lianas and ferns, or gorgeously-blossomed cactuses, orchids, and passion-flowers. The vast plains or *llanos* of the Orinoco, with their tall grasses and occasional clumps of pines and mimosas, represent the pasture lands of the Old World, but with their bright lilies show a brilliancy of colour peculiar to themselves. Further south the basin of the La Plata presents similar plains or *pampas*, which, getting less and less luxuriant in their vegetation, are at length succeeded by the barren moors of Patagonia and Terra del Fuego. On the lower mountain slopes, characteristic trees are cinchonas, from the bark of which quinine is prepared. Mahogany, rosewood, the indiarubber tree, with many plants yielding spices, balsams, and perfumes, give a distinctive character to the South American flora. On the more elevated tracts, calceolarias, gentians, and low-growing plants occur, that remind the traveller of some features of mountain vegetation near the snow-line in the Old World.

19. The fauna of this region is regarded as more varied than that of any other. It contains the peculiar jaguar, flat-nosed monkeys, and marmosets, blood-sucking bats, chinchillas, sloths, armadilloes, ant-eaters, racoons, opos-

sums, deer, llamas, alpacas, vicunas, tapirs, and peccaries; but no native sheep or oxen. Among the birds occur condors, curassows, rheas, or American ostriches, toucans, jacamars, mot-mots, macaws, and numerous forms of humming-bird. The reptiles include the boa-constrictor and many other serpents, the alligator, crocodiles, tortoises, and turtles. The insect life is immensely abundant and varied.

20. (vi.) **The Nearctic Region** embraces all North America lying to the north of the tropic of Cancer. Its greatest breadth being towards the cold northern regions, it rapidly narrows southward, so as to be connected with the Neotropical region merely by a narrow strip of land. This isolation is accompanied by a somewhat less varied flora and fauna than in the corresponding region of the Old World. The plants and animals, taken as a whole, present much less contrast to those of the Palæarctic region than those of the Neotropical and Ethiopian regions do to each other. The northern tracts of North America extend far within the Arctic circle, into the snow-covered lands where vegetation reaches its lowest point of development. The southern limits of the province, on the other hand, lie towards the tropical zone, where the sugar-cane, yucca, cotton, maize, and tobacco are characteristic plants. In California and Oregon many large and distinct kinds of pine occur in the forests, such as the gigantic Wellingtonia and the Douglas pine. Eastward of the Rocky Mountains vast undulating pasture lands or prairies stretch over the basin of the Mississippi. The British Possessions lie mostly upon forests, which, as the country becomes peopled, are gradually giving way to pasture and cultivation.

21. The fauna varies with the latitude. In the north are found musk-sheep, moose-elks, reindeer, gluttons, skunks, racoons, beavers, lemmings, jumping-mice, and tree-

18. (v.) **Neotropical Region.**—Under this term are included the whole of South America, the islands of the Antilles group, and the tropical part of North America. Ranging across the whole zone of the tropics, and as far south as the 56th parallel of south latitude, and rising up to the snow-line in the Andes, this region presents many varieties of climate, which are well shown by differences of vegetation. The lower grounds within the tropics present the most luxuriant flora in the world. It abounds in mangroves, palms (cabbage-palm, ivory-palm, and other kinds), bananas, tree-ferns, and mimosas, growing in dense jungles, and having their stems and branches clustered round with many smaller plants, such as lianas and ferns, or gorgeously-blossomed cactuses, orchids, and passion-flowers. The vast plains or *llanos* of the Orinoco, with their tall grasses and occasional clumps of pines and mimosas, represent the pasture lands of the Old World, but with their bright lilies show a brilliancy of colour peculiar to themselves. Further south the basin of the La Plata presents similar plains or *pampas*, which, getting less and less luxuriant in their vegetation, are at length succeeded by the barren moors of Patagonia and Terra del Fuego. [illegible] the lower mo[illegible]in slopes, characteristic trees are [illegible]
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[illegible]s, slo[illegible] [illegible]oes, an[illegible] [illegible]acoons, or

1st. Climate. 2nd. Migration and transport. 3rd. Changes in the form and height of the land and in the depth and extent of the seas. A knowledge of the nature and effect of these influences helps us to understand much that would otherwise be inexplicable, but there still remain, and perhaps must ever remain, many difficulties which no amount of research may be able to remove.

I.—Climate.

4. This term includes the general temperature, moisture, winds, and other atmospheric conditions which prevail in any district, and which directly affect the growth and vigour of plants and animals. From the statements made in Lesson IX. it appeared that the climates of different portions of the globe greatly differ, and some of the causes of such differences were there traced. But a knowledge of the annual distribution of heat at any place, though it gives us one main element in determining the climate of that place, requires to be enlarged by further knowledge respecting the rainfall, the direction of the prevalent winds, the shape, height, and position of the ground, the character of the soil, vegetation, and other more local details. Since Lesson IX. you have been led over most of these subjects, so that you may now return to the question of climate in reference to the arrangement of plants and animals.

5. On consideration we may recognise five distinct influences by which the climate of any place is determined. 1st. Distance from the equator. 2nd. Distance from the sea. 3rd. Height above the sea. 4th. Prevailing winds; and 5th. Local influences, such as soil, vegetation, and proximity to lakes or to mountains. Each of these causes directly, and often powerfully, controls the spread of vegetable and animal life.

porcupines. Further south vast herds of bisons roam over the prairies. Other typical animals are the grizzly bear, black bear, puma, lynx, prong-horned antelope, prairie-dog, flying-squirrel, pouched-rat, opossum, humming-bird, blue-crow, and rattle-snake.

LESSON XXXI.—THE DIFFUSION OF PLANTS AND ANIMALS.

Climate.—Migration and Transport.—Changes of Land and Sea.

1. IT is not enough to know how the various tribes of plants and animals are distributed over the surface of the globe. We are irresistibly led to ask ourselves why and how their distribution has come to be as we have traced it in the preceding lesson. Not very long ago men were content with supposing that the present arrangement had always existed ever since the different continents and islands rose out of the sea and received their earliest inhabitants.

2. But in [illegible] nd clay [illegible] th the soil, or in the limestones [illegible] and ot[illegible] lying below, traces have been [illegible] r the [illegible] older and different plants a[illegible] which [illegible] he land before the present [illegible] d app[illegible] modern horses and [illegible] were [illegible] y other kinds which [illegible] T[illegible] hyænas of [illegible] same [illegible] teeth and [illegible] ca[illegible] osits. [illegible] st[illegible] s three [illegible] whic[illegible] ribution [illegible] of [illegible] urface.

8. But these differences are not merely marked by the variations in the growth of the same plants. As shown in the last lesson, when we pass from one climate to another we encounter different plants and different animals. One by one characteristic forms of life drop away and their places are taken by others. So constant and marked are these changes that such expressions as "an arctic vegetation," "a temperate flora," "a tropical fauna," have passed into general use, and convey a distinct picture to the mind.

9. We have found, however, that if such a distribution of plants and animals were due to differences of climate alone, wherever the same climate recurs it should be accompanied by the same kind of vegetation and of animal life, but that no general coincidence of this kind exists, when regions remote from each other are compared. The climate of the centre of Europe closely resembles that of parts of the United States. Yet the wild animals and birds are strikingly different; mice, hedgehogs, buffaloes, chamois, and jays in the Old World are replaced by jumping-mice, racoons, oppossums, bisons, llamas, and humming-birds in the New. In central South America the forests are tenanted by jaguars, sloths, armadilloes, tapirs, curassows, and toucans. On corresponding latitudes in equatorial Africa these animals are represented by lions, leopards, hyænas, hippopotamuses, elephants, guinea-fowl, and touracoes. In Australia these forms are again replaced by a strange and peculiar assemblage of animals, including kangaroos, wombats, flying-opossums, emus, lyre-birds, and crested pigeons. While therefore difference of latitude usually means difference of climate and of plant and animal life, identity of latitude with similarity of climate dces not necessarily imply agreement in the character of the flora and fauna.

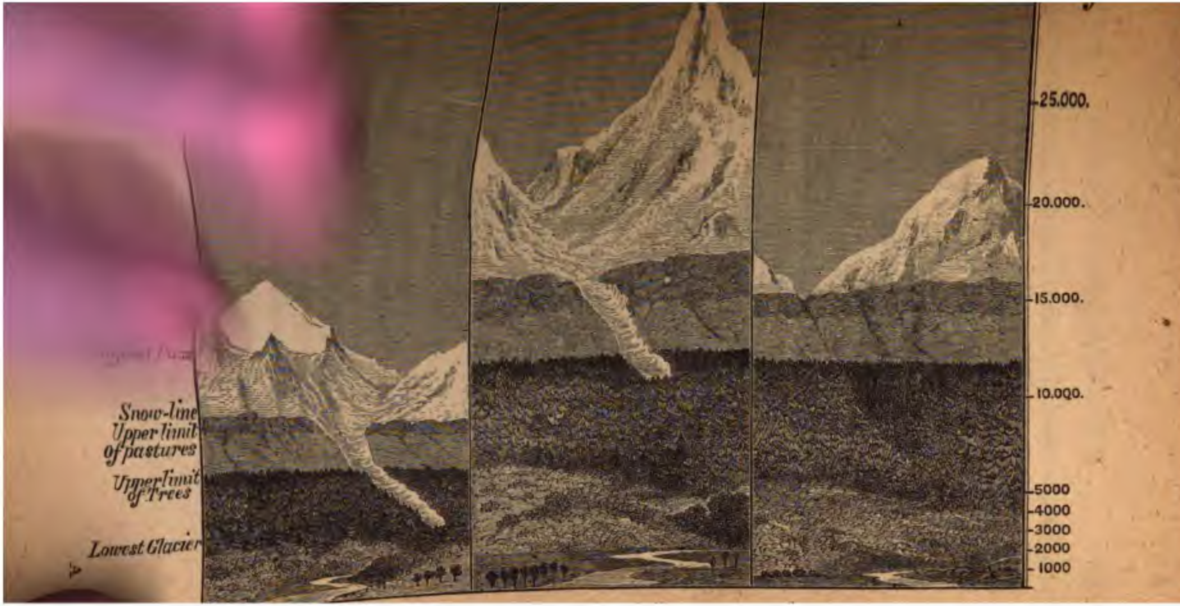
10. (ii.) **Distance from the Sea.**—The influence of the

sea upon the distribution of temperature and moisture has been already described (Lessons IX., X., and XVIII.). As water is more slowly heated and cooled than land, the climates of the sea and of the coasts of the land are much more moist and equable than those of the interior of the land. In proportion therefore as places recede from the sea their climates become more extreme. An insular or oceanic climate is one where the difference between summer and winter temperature is reduced to a minimum, and where there is a copious supply of moisture from the large water-surface. A continental climate is one where the summer is hot, the winter cold, and where the rainfall is comparatively slight.

11. These variations cannot but make themselves visible in the distribution of plant and animal life. They are well shown by contrasting the times of flowering and ripening of the same plants along the Atlantic border and in the central countries of Europe. It will be remembered that owing to the influence of the warm Atlantic water the temperature of the whole of the north-west of that continent is raised considerably higher than it would otherwise be. Consequently vegetation is much earlier in the south of Sweden than in the same latitudes to the east. The lilac and elm begin to show their leaves sooner at Upsala than at Paris, and while winter still reigns to the east of the Baltic, spring blossoms have already spread far up into Scandinavia.

12. The difference between an insular or oceanic and a continental climate is likewise well brought out by the fact that such evergreens as the Portugal laurel, aucuba, and laurustinus grow luxuriantly even in the north of Scotland, while they cannot withstand the severe cold of the winter at Lyons.

13. (iii.) **Height above the Sea.**—In Lesson IX. Art. 20 reference was made to the gradual diminution of temper-



Snow-line
Upper limit of pastures
Upper limit of Trees
Lowest Glacier
A
25,000.
20,000.
15,000.
10,000.
5000
4000
3000
2000
1000

apt to be hot and suffocating in summer, piercingly cold and dry in winter. Winds which come from lower into higher latitudes, or from warmer to cooler climates, have their moisture condensed, and are therefore rainy, while those which blow from higher to lower latitudes, or from cold to warm regions, are dry.

15. Much, therefore, in the climate of any place must be due to the prevailing winds. This is more particularly noticeable on the coasts of the continents, where the winds blow alternately from and to the sea. The striking contrasts between the extremely rainy and almost rainless districts in certain parts of India have already been referred to as showing the great influence of the winds in determining the moisture of a climate.

16. It is evident that, as regards plant-growth, moisture is hardly less important an element than temperature in the climate. Those tracts are most plentifully covered with vegetation which are most copiously watered. Both the character and the abundance of the vegetation depend greatly upon the amount of rain-fall. The west side of the British Islands, for example, which receives the first and largest precipitation of the moisture borne by the south-westerly breezes from the Atlantic, is much greener and more luxuriantly clothed with vegetation than the east side.

17. Whatever regulates the growth and distribution of plants must tell effectually upon the spread of animals. The herbivorous species naturally haunt those regions where their supplies of vegetable food are most abundant. In their train come the predatory kinds which prey upon them. Any change of climate, therefore, unfavourable to the vitality of the pasture will drive away or even locally exterminate the herds of plant-eating animals, and when they disappear the beasts of prey must vanish also.

18. (v.) **Local Influences.**—Various minor causes of a

e local kind help to modify the climates of different es, and thereby to affect the flora and fauna. The ire of the soil is one of the most important of e. Wet, marshy ground lowers the mean tempera-, seeing that its water absorbs and conveys down-l the heat which would otherwise warm the soil. sequently the effect of drainage is to raise the mean ıal temperature. In Britain this increase amounts etimes to as much as $1\frac{1}{2}°$—$3°$ Fahr., which is as great ange as if the ground had actually been transported or 150 miles further south. A waste of sand presents greatest extremes of climate, for while the dry surface ily absorbs the sun's heat so as to rise even to 200° r. during the day, it cools rapidly by radiation, and ng a clear night may grow ice-cold.

). A surface of vegetation prevents the soil from being ıuch warmed and cooled as it would be if bare, and aves never become so hot as soil, they equalise the perature. A large mass of forest thus exercises a marked influence on the climate of the region on h it lies, tempering alike the heat of the day and the of night.

). Similar effects are produced by lakes and other inland surfaces of water. The surface water chilled old of winter descends to the bottom, leaving a er at the top, which, cooled in its turn, sinks allows another warmer portion to lie at the y this means the temperature of the air over-ater is kept above that of the air overlying the and, wh lder air from all sides flows e lake warmed. Many deep lakes hen serve as reservoirs of e of the surrounding ground ly a short distance away. On mer the water cools the air

lying upon it, and thereby lessens the heat of the locality.

21. One other local cause affecting climate may be referred to, viz., proximity to hills or mountains. The influence of high ground shows itself in augmenting rain-fall (Lesson X. Art 29), in producing currents of air, which move alternately up and down the valleys (Lesson XI. Art. 8), giving rise to gusts and blasts of cold wind, which rush down to the plains.

22. It was formerly imagined that each climate had its own characteristic forms of life, and that the boundaries between the different botanical and zoological regions were as ancient and as well defined as between the various climates. But while similarity of climate does not always bring similarity of vegetation and of animals, the want of resemblance between the plants and animals of two distant countries having similar climates does not arise from any unfitness in the one country for the organisms of the other. Cattle and horses introduced by the Spaniards into South America now run wild there in vast herds. The rat, originally not a native of America, may now be found in all parts of the continent. Hogs, goats, cats, and dogs, first brought into the New World by Columbus and his successors, are to-day found running wild in great numbers. In Australia, too, the domestic animals introduced by the colonists are rapidly supplanting the kangaroos and other aboriginal forms. A fresh-water plant accidentally imported from America has spread rapidly over England, and is choking up canals and the channels of rivers.

23. We must conclude that similar climates may have remarkably dissimilar assemblages of plants and animals if they are sufficiently isolated from each other, that such differences are not referable to the influence of climate, for the plants and animals have been found to increase

dly when transported to a distant but similar climate, that while climate has evidently an important innce in the distribution of life over the globe, it is not icient to account for all that we see.

II.—Migration and Transport.

4. It might be supposed that the present plants and mals first appeared in one region or continent, whence y gradually spread over the whole of the globe. No ıbt many species are endowed with remarkable powers diffusing themselves and of living even vigorously ler the greatest extremes of climate. But further coneration suffices to convince us that this explanation is olly incapable of accounting for the existing arrangent of the faunas and floras of the earth.

15. Plants have many facilities for spreading themselves. ieir seeds are often swept up into the air by whirlwinds, d may be carried along for hundreds of miles before ing dropt again to the ground. Should the soil, climate, d other conditions be favourable, these transported eds may take root and spread over their new abode. other cases, seeds may be borne for long distances er the sea, either floating by themselves or inclosed ıong earth and leaves in masses of drift-wood. Cast up last on some remote shore, they sometimes find a fitting me ... root th... o the feathers of birds and ... ten adhere, and may thus ... r original source. Seeds ... urs in the crops of birds ... e. It may now and then ... ıfter flying across hundreds ... other predatory ... from their torn ... ventually ...

spring into leaf. In these and other ways many kinds of plants may have spread far beyond their original bounds. Yet at the best these are but limited means of transport. Differences of climate and soil, lofty mountain-chains, and intervening seas have placed barriers in the way of such diffusion which comparatively few species of plants can ever surmount.

26. Animals enjoy greater facilities for dispersal, since their movements are voluntary as well as involuntary. On some of the large tropical rivers rafts of drift-wood are now and then to be seen with monkeys and other wild animals upon them, all sailing down the current on their way to the ocean. In the great majority of cases rafts of this kind are broken up at sea, and their unfortunate denizens are drowned. But cases have been known where the animals have actually found their way to land. We may suppose therefore that islands in mid-ocean may sometimes have had both plants and animals introduced into them by these means. Again, in the Arctic seas, polar bears have been noticed upon icebergs at a great distance from land; so that by drifting ice as well as by floating vegetation, animals may be diffused from one country to another. But here again the means of transport are so scanty and the chances of the animals being able to live and multiply in their new home are so small, that we may be sure it is not in this way that the continents have been peopled.

27. While most animals live within tolerably well-defined limits, marked out by the climate and the kind of vegetation which the climate supports, some species have great powers of migration, and when impelled by their migratory instinct, whether from stress of hunger, or from change of season, will travel for hundreds or thousands of miles. In North America many remarkable instances are on record of the hordes of bisons, beavers, and squirrels

ich from time to time have quitted their previous ha
search of a new home. Birds show this ins
ongly. Many of the most familiar birds of the tempe
ion, both in the Old and the New World, are migra
ey go north in summer to breed, and after spen
ne months in a cooler climate, and seeing their yo
ood able to fly, they again take wing and return to
nter quarters in the south. In Europe the swift, swa
d cuckoo wing their way in summer even far up w
e Arctic Circle, but before winter has set in they
ossed the Mediterranean to the milder air of Nort
rica.

28. But while a limited number of animals are f
spread over wide regions and to endure great diver
climate, the vast majority are confined within
wn district, beyond which they cannot stray, not bec
ey are in all cases unfitted for distant journeys.
ecause of the insuperable barriers to their advance.
ese obstacles the most potent is no doubt climate, w
cts not only on the animals themselves, but on the
ation, which directly or indirectly furnishes their
ome species of animals can live only in woods, o
annot stray far from the marshes and jungles, where
hey find their proper support; some are adapted fo
olely in the moist hot air and luxuriant vegetation c
ropics; others find their congenial home among
nows.

29. Even, how[illegible] endowed, li
iger, with extr[illegible] mmodating
o wide extre[illegible] at variety of
it is surrou[illegible] its diffusio
lofty snow-[illegible] ually p
it from cr[illegible] once
them, it [illegible] helte
strip o[illegible] s b

[illegible]

[illegible] passing over
[illegible] a few miles
[illegible] animals of the
[illegible] wide and deep

[illegible] some experi-
[illegible] animals of the
[illegible] one of these
[illegible] will be
[illegible] The
[illegible] increase
[illegible] look
[illegible]

plant and animal have been able to diffuse themselves
er almost the whole globe, the flora and fauna of each
the great biological regions remain distinctly marked
t by more or less definite boundaries. That these
gions have in every case had a long history, and that
eir existing species of plants and animals have been
eceded by other and different species, is shown by the
cks which form the land, and the traces both of vegetable
d animal life found in these rocks. In trying to discover
w and whence the continents have received their mantle
vegetation and their hosts of animals, science needs to
ope backwards among the records contained in the
cks, and which form the subject of Geology. To some
pects of this question, which show how closely Physical
eography is linked with Biology, how the plants and
e animals of a continent may be made to tell a part of
e ancient history of the land on which they live, the
oncluding pages of these Lessons may fittingly be given.

III.—Changes of Land and Sea and of Climate.

32. From the facts recorded in the preceding Chapters
appeared that the present heights and hollows of the
and have not always existed,—that the continents have
een uplifted at different times from the bed of the sea,
hat each mountain-cha... as been ridged up and altered
... eriods, an... he valleys have been slowly
d wider ... ivers flowing in them. We
... rtant changes could take
... less potently the various
... Investigation shows that
... re so... bears striking
... these ... How this is

made evident will be clear from one of the simpler illustrations.

33. The plains of Central Europe up to the shores of the Baltic are clothed with a vegetation which has one common character throughout. Many of the plants are of course local, but a vast number range far and wide over the region. Crossing from the continent into Britain we meet with the same general assemblage of plants, and as the greater number of these could not have been drifted across the intervening sea, but must have travelled by land, they show that originally Britain formed a part of the European continent, and that its separation into islands has taken place since the present species of plants spread over its surface.

34. Any one who ascends the higher hills in Britain, or a part of the mountain-chain of the Alps or the Pyrenées, finds that as he reaches higher elevations he loses the common and characteristic plants of the plains. The vegetation as it becomes less luxuriant assumes a more and more distinct type, not only by the disappearance of lowland species, but by the occurrence of others, such as peculiar gentians and saxifrages never seen below, but plentiful on the higher hill-tops and mountain slopes. So general is this change that every hill or mountain in Central and Northern Europe, rising high enough to reach the fitting climate, may be expected to contain more or less fully this alpine flora. And this is found to be the case even when the groups of mountains are separated by wide intervals of low country. The Scottish Highlands furnish on their higher slopes an abundant growth of alpine forms of vegetation. Crossing the Lowlands, where none of these plants occur, we again meet with them on some of the more elevated summits in the Cheviot Hills. After another interval they reappear on the hill-tops in the Cumberland

lake-district, and again on the higher mountains of Wales. Across the whole breadth of England they are absent from the low grounds. They are not to be found on the opposite shores of the Continent. But far to the south they reappear abundantly on the tops of the Pyrenees and below the snow line along the whole chain of the Alps.

35. We must not suppose these plants to be merely species peculiar to lofty elevations and always found there. They do not occur on mountains lying to the south of the Palæarctic region. On the Peak of Teneriffe, for instance, they are absent, though the climate and soil would have been well fitted for them. On comparing the heights at which they are met with we perceive that they approach nearer the sea-level the further north we trace them. In the Alps they grow in the zone between the upper limit of trees and the snow-line, or at a height of from 6,000 to 10,000 feet above the sea. In the Scottish Highlands they descend to 2,000 feet, or even lower. In Scandinavia they come down to the sea-level, and grow in such vigour and abundance there as to show that they are really northern or arctic plants.

36. How then did an arctic flora overspread the mountains so far south as the Alps? It could not do so at present. The intervening low grounds are clothed with an abundant vegetation of ... type, across which the northern plants could not ... way. To enable them to advance ... land vegetation would need to ... mate of Central Europe were ... of Norway or of the higher A... would be to kill the vegetati... could not endure th... the arctic plants, fin... ling across

the European plain, would gradually spread southwards, ascend the hills, and finally become the dominant vegetation over the whole region where the arctic climate prevailed. This seems to be the only way in which the presence of hundreds of northern plants upon the Alps and Pyrenees can be satisfactorily explained.

37. Is there then any corroborative evidence that such a wonderful change in the aspect of Europe did really take place? Undoubtedly there is. Below the soil in different parts of France and England, as well as in the deposits covering the floors of caves, bones of reindeer have been found in considerable abundance. This we know is an arctic animal. Remains also of the musk-sheep, glutton, arctic fox, lemming and others, which are all northern forms, have been exhumed from similar situations. So that there can be no doubt that at one time characteristic animals of the arctic regions roamed over Europe as far at least as the south of France. We cannot doubt that this could have happened only through some change of climate which, driving out the usual denizens of the plains and forests, allowed the northern animals to occupy their place.

38. But further and abundant proof of an extremely rigorous climate having overspread Europe is supplied by the polished rocks and heaps of earth, which were described in Lesson XXVIII. as part of the work of glacier-ice. Traces of former glaciers are found throughout the more hilly districts of Britain. Similar traces occur both in Norway and among the Alps and Pyrenees, far beyond the limits of the present glaciers, showing that the ice formerly extended in vast sheets into the plains.

39. It was during this cold period that the arctic plants and animals overspread Europe. Since that time the climate has gradually ameliorated. Step by step the

ɪrthern plants have been driven out of the plains and up to the mountains, where among the congenial frosts and ows they are able to maintain themselves in scattered lonies. The animals have long since been pushed back to the icy north.

40. In North America a similar record has been preved. As far south as the White Mountains of New mpshire in the United States (lat. 45°) the summits peopled with Labrador plants, which once no doubt nded over the low grounds up into the northern lands, re the same species are now found abundantly down he sea-level.

1. This illustration—by showing how far the present tribution of plants and animals may be from that which ce existed, and also how distinctly groups of plants of animals may sometimes tell of former changes in hysical geography—may serve to indicate why the problem of accounting for the existence and differences of the iological regions should be so difficult. So many causes ave to be considered and so much knowledge is needed garding the events which preceded the present state of ings. Much has been done by naturalists in this dertment of research during recent years, but they have yet only entered upon the beginning of the inquiry. he peopling of each of the great regions with mals may never be fully told. But that it far fuller and clearer than it is, and that it ustrate the history of the continents thembe doubted.

rand object of science is to link the present to show how the condition of the globe toес, to trace the progress ng ages to their earliest ınt life now teeming in

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